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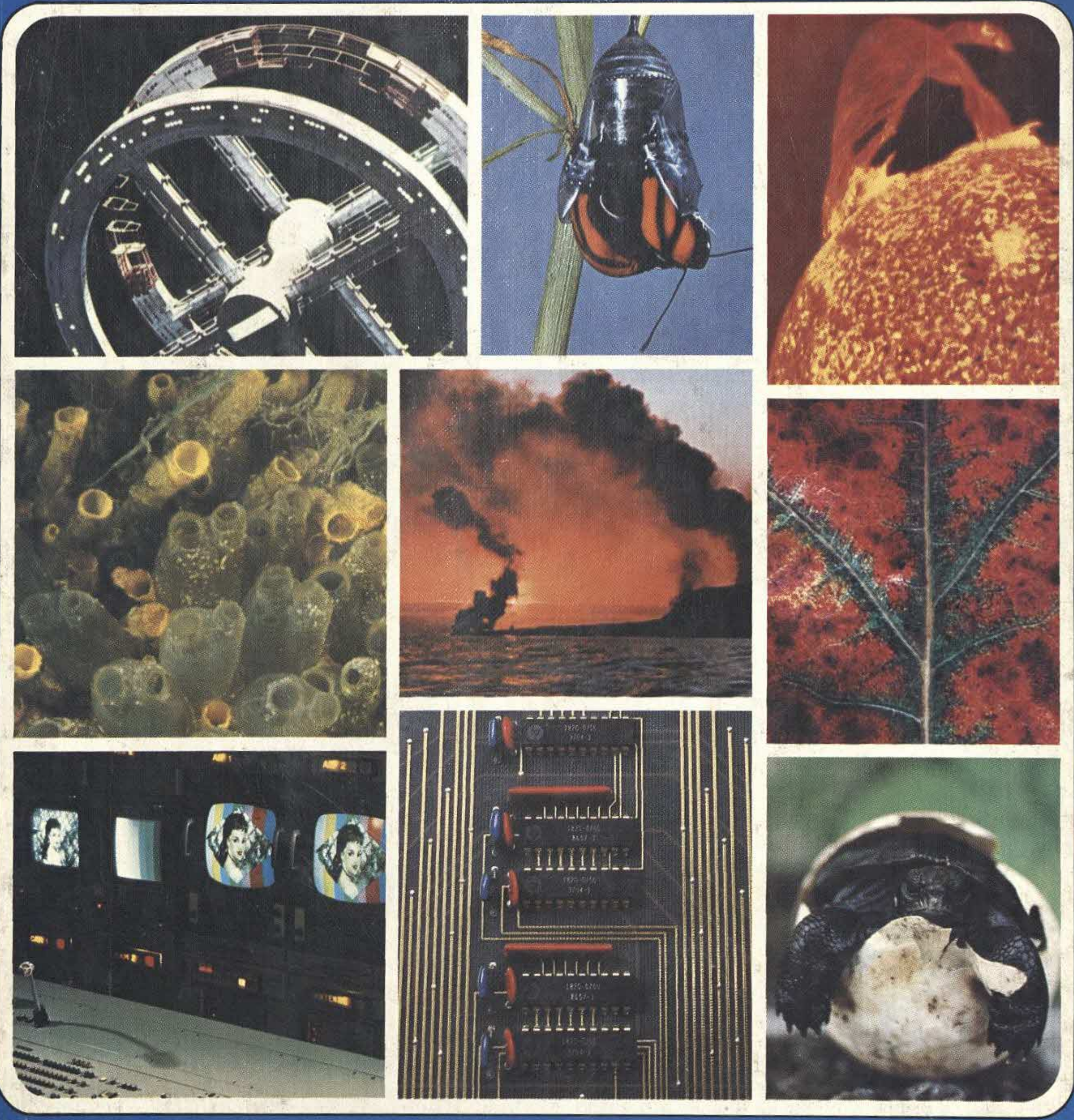
THE NEW BOOK OF POPULAR SCIENCE



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THE NEW BOOK OF
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VOLUME 5

Mammals
Human Sciences

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Above: J. Six
Left: Tom Myers

Mammals are the dominant animals of the world. They are able to live in and respond to varying conditions—but usually only after a prolonged period of parental care. Opposite page: adult male orangutan. Above: vole, which lives in Europe. It is closely related to the muskrat and the lemming.

Norman Myers/Bruce Coleman Inc.

Cheetah with her young.

MAMMALS

by Ian McT. Cowan

The animal class of the mammals, or Mammalia, includes a great many familiar forms—horses, cows, dogs, domestic cats, rats, mice, sheep, goats, and rabbits, to name only a few. It also numbers such exotic creatures as elephants, giraffes, rhinoceroses, gorillas, sperm whales, dolphins, vampire bats, kangaroos, and platypuses. All these animals, familiar and exotic, have certain features in common. They are *vertebrates*, or animals with backbones. They have large brains and a keen awareness of their surroundings. They are warm-blooded and possess a waterproof skin more or less covered with hair. The young are born alive, except for the platypus and spiny anteater, and suckle milk from the *mammary,* or milk, *glands* of the female. The word "mammal" comes from the Latin *mamma:* "breast," a glandular organ that secretes milk.

The mammals, including humans, are the dominant animals of the world. They live wherever life is possible—on

Arctic ice sheets and in tropical rain forests, on mountain crags and more than a kilometer below the surface of the sea, in underground burrows and at the tops of the tallest trees, in freshwater lakes and streams and also in the air. They vary in size from the minute pigmy shrew of North America – five centimeters in body length and weighing about as much as a dime – to the blue whale, a giant 30 meters long and weighing some 120 metric tons. Today there are roughly 3,500 distinct species of mammals. There are about 15,000 species and subspecies.

REPTILE ANCESTORS

Mammals are comparative newcomers to the animal population of the earth. We can trace their descent back to the *cotylosaurs,* a reptile group that lived in the Carboniferous period, about 300,000,000 years ago. The cotylosaurs were sluggish and clumsy animals that crawled on their bellies with legs sprawled to the side. Many of them probably lived in or near water, but laid their tough-shelled eggs on dry land.

From the cotylosaurs, directly or indirectly, evolved all of the reptiles: the modern forms – turtles, crocodiles, lizards, and snakes – and those that we know about only from fossil remains. The cotylosaurs were also ancestors of the animals known as mammal-like reptiles.

REPTILE TO MAMMAL

The mammal-like reptiles began their evolution some 280,000,000 years ago. Some were carnivorous, or flesh-eating; others, herbivorous, or vegetation-eating. They all had one feature in common: a hollow in the skull behind the eye, which accommodated large jaw muscles. In time the mammal-like reptiles became more and more like mammals. By about the beginning of the Jurassic period, some 180,000,000 years ago, a population of carnivorous mammal-like reptiles seems to have given rise to small animals that clearly possessed the characteristics of mammals. The mammal-like reptiles themselves became extinct.

Body supports. How did a sluggish, sprawling reptile develop into an active, warm-blooded mammal? We mentioned that the cotylosaurs crawled on their bellies. During the rise of the mammal-like reptiles, a gradual lengthening of the front and hind legs took place. The feet came more and more to point forward instead of to the side, and the legs were brought in under the body. Thus the body was lifted off the ground. The bones of the pelvis fused to form a single bony structure. These changes permitted the animals to move about more efficiently and rapidly.

Teeth. Another change affected the na-

Mark Newman/ © Animals Animals

A young female horse is called a filly; and a young male horse is called a colt.

ture of the teeth. From a row of simple, spikelike teeth, which the reptiles possessed, there developed the incisors, canine teeth, and cheek teeth, or molars, of the mammals. These teeth were set in sockets of the jaw. On the crowns of the molars evolved several cusps, or points. The mammal's teeth could more efficiently nip off pieces of food, shear, and grind it.

Skull and brain. The bony case enclosing the brain expanded during the evolution from mammal-like reptile to mammal. This permitted greater brain growth and development. Especially important was the development of the *cerebral cortex,* a covering of gray matter over the cerebral hemispheres. The cerebral cortex is a complex area of nerve cells. It is concerned with higher processes such as thinking and reasoning.

Circulation and temperature control. A further change involved the heart, which came to be divided into four chambers. Through this development, blood carrying oxygen from the lungs to the heart is kept entirely separate from the blood pouring into the heart from the rest of the body. As a result, the tissues constantly receive a rich supply of oxygen, picked up in the lungs.

Oxygen is necessary for converting food substances into energy. The food of mammals is broken into small pieces, through chewing, before being swallowed. Consequently it can be quickly digested in the stomach and intestine. The digested food particles are rapidly transported to the tissues by the circulatory system.

Dogs. familiar domestic animals, are members of the order of carnivores. Carnivores are specialized for hunting medium- to large-sized prey.

Bruce Coleman

With a greater supply of oxygen and food in its tissues, there is a greater output of energy. Some of this goes into muscular work, making the mammal more active. Some takes the form of heat, which, carried by the blood, warms the body and causes many of its chemical reactions to proceed at a quicker rate.

As body temperature rises, the mammal's body requires more fuel or food, a greater consumption of oxygen, and a higher production of carbon dioxide and other waste products. As a result, blood circulation is increased. Of course this requires increased filtration of the blood by the kidney.

The kidney of a mammal not only filters the blood of salts, sugar, water, and wastes, such as urea, but also reabsorbs the sugar and most of the salt and water. Consequently a highly concentrated urine is produced, and water is conserved within the body.

The mammals developed a covering of hair, insulating the body against both excessive heat and cold. They also evolved an efficient control of their surface blood vessels. Because of this, blood can be turned, or shunted, away from the surface when body heat needs to be conserved during cold weather. In hot weather and during physical activity, the body temperature is kept down by dilating, or widening, these same surface blood vessels. They then radiate heat; they also lose a watery fluid that escapes to the skin surface by way of the sweat glands. When a mammal sweats, the skin is moistened. Evaporation of this moisture cools the body.

Care of young. The milk glands of mammals secrete a rich, balanced, liquid diet for newborn offspring. Because this offspring depends for survival on its mother's milk, it is under parental care for some time.

The extended period of infant care further distinguishes the mammals from the

Paolo Koch, Rapho/PR

Mammals have evolved many special features. This wild goat has a magnificent set of horns that it can use to defend itself from enemies.

reptiles, which usually do not give further attention to their young once the eggs are laid or the young are born.

During the period of infant care, the young mammal has time to develop and learn a variety of reponses. When it leaves the protection and guidance of its parent, it is fitted to modify its actions in the face of varying circumstances.

RISE OF MAMMALS

We pointed out that the first mammals probably arose about 180,000,000 years ago. These primitive mammals evolved into different types.

One group, the *monotremes,* has persisted down through the ages and is represented today by the platypus and spiny anteaters. They have fur and feed milk to their young, but they are very much like reptiles in many respects. For example, the waste products of the intestine, the urine, and the sperm or eggs pass into a common chamber, called the *cloaca,* from which they are discharged. The name "monotreme" means "single hole" (referring to the opening of the cloaca) in Greek. This is the condition found in reptiles.

Another group of primitive mammals, called *pantotheres,* was made up of small creatures that ate almost anything. In the early Cretaceous period (130,000,000 years ago), the pantotheres gave rise to the *marsupial* mammals on the one hand and the *placental mammals* on the other.

The young of marsupial mammals are carried, from a very early stage of their development, in a marsupium, or pouch. Placental mammals retain their young within the body until development is quite complete. The name "placental" is derived from the placenta, a structure by means of which the fetus is nourished and discharges wastes in the uterus, or womb. These two groups changed but little during the long Cretaceous period, which lasted some 70,000,000 years.

By the end of the Cretaceous period some 60,000,000 years ago, the dominant reptiles had dwindled in numbers or had become extinct. Cold and dry uplands had been created by the building of mountains and other geological changes. In these uplands the large reptiles were at a fatal disadvantage. The mammals, however, flourished under the changed conditions because they were warm-blooded creatures, with internal body temperature control and also because of their unrestricted diet, their exploratory activities, and their more efficient means of reproduction. The extinction of most of the reptiles left empty environments that could be filled by the mammals. The marsupials and placentals adapted to these new niches, changing more and more in form and habits.

The female of the marsupial, as we have noted, rears her young in a special pouch on her belly. The marsupial embryo develops from a comparatively large-yolked egg cell in the female's uterus, or womb. While in the uterus, the embryo receives little or no nourishment from the mother. The young is born in a very undeveloped condition. For example, the newborn opossum is no larger than a bee. It crawls into the shelter and warmth of the pouch, where the mammary glands are located, and hangs on to one of the nipples. Milk is pumped into the young by the mother. The young remains in the pouch, attached to a nipple, until development is complete. Then it leaves the pouch to feed on its own, but frequently returns for protection.

Placental mammals differ in their manner of reproduction. The embryo develops from an egg cell having very little yolk. A membrane surrounding the embryo fuses with tissue lining the uterus of the female. This complex intergrowth of tissues from the wall of the uterus and from the embryo is the *placenta*. In this structure, blood vessels from the mother's and embryo's circulatory systems come into close contact. Though there is normally no exchange of maternal and embryonic blood, dissolved substances are transferred between the two systems. Food and oxygen diffuse from the mother's blood into her developing young. Carbon dioxide and wastes, such as urea, are given off by the embryo to the maternal blood stream. When the young placental mammal is born – that is, delivered from the mother's uterus – it is in an advanced stage of development.

The placentals also differ from marsupials by having a more expanded brain case and a greater development of the cerebral hemispheres. They lack the cloaca, or common chamber for wastes and sex products, found in all the monotremes and marsupials. They are often more aggressive and efficient than the marsupials. However, in Australia, the pouched mammals survive despite introduced placentals that compete with them.

MAMMALS IN THE ENVIRONMENT

Mammals do not live in a vacuum. They must cope with the many factors of their environment – temperature, humidity, light, vegetation, other species of animals, and members of their own species. Some mammals are less adaptable than others. For example, the giant panda can live only in bamboo forests, subsisting on bamboo shoots. The koala, which is an Australian marsupial resembling a teddy bear, survives only if the leaves of one or two kinds of eucalyptus trees are available to it for food. On the other hand, the brown rat can live almost anywhere and eat anything and, consequently, has spread over most of the globe.

Temperature. Though mammals are warm-blooded and generally control their internal temperature, the external temperature affects them. The white rat, for example, can maintain a nearly constant temperature when outside temperatures range from −25° to 40° Celsius. If the outer temperature goes much beyond these extremes, the animal's own temperature regulation breaks down, with fatal results.

Arctic foxes are active in winter even when the temperature drops to −50° Celsius. During blizzards the animals dig shelters in the snow. On the other hand, the armadillo, woodchuck, hamster, and some other rodents hibernate during winter. Their body temperature actually falls to a level only slightly above that of the environment. Bears also sleep in winter, but this is not true hibernation. By burning a rich store of body fat, their body processes continue at a rate that is only slightly lower than normal.

Humidity and water. High humidity is important for small bats, because their wing membranes dry out if the humidity falls much below 85 per cent. Moles also require dampness, and their burrows are usually very humid. They will die if forced from their burrows by a prolonged dry spell.

The abundance of water is very important, because many mammals drink a great deal. The large African herbivores, such as the antelopes, zebras, elephants, giraffes, and buffalo, regulate their movements according to the water sources. These

An arctic wolf wearing her winter coat. It helps her blend in with the snow.

Schraml—Jacana

sources are also vitally important to animals such as lions, leopards, and hyenas. Not only do they need water themselves, but they find their prey among the herbivores that live in the general vicinity of water holes.

Some mammals drink dew or rain water running off foliage when there is no temporary or permanent water supply. Others get along with the water contained in their animal or vegetable food. This is true of many carnivores, rabbits, and hoofed mammals, as well as certain desert rodents, such as pocket mice and kangaroo rats.

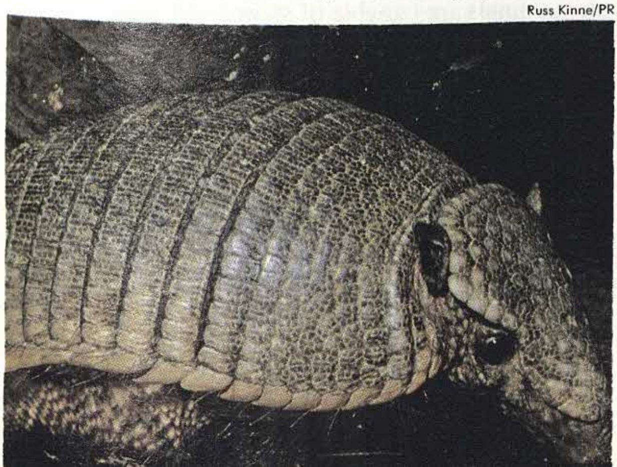
Light. Light is another environmental factor that affects mammals. A great many species remain secluded during the day and become active only at sundown or after dark. This is true of numerous small mammals, such as bats, flying squirrels, badgers, shrews, rats, mice, anteaters, and raccoons, to mention a few. Other species, including moles, monkeys, tree squirrels, and ground squirrels, are most active by day. The large-hoofed mammals and cats, foxes, coyotes, and rabbits may be active day or night.

In addition to regulating daily activity, light also controls the time of mating in some mammals. For example, the reproductive glands of the ferret mature as the amount of daylight increases each day during the spring. On the other hand, with such mammals as goats and deer, a decrease in the amount of daylight per day, as in the fall, stimulates reproductive activity.

Light may also govern the molting cycle. The *pelage,* or hair, of mammals is shed in periodic molts. Some mammals molt in spring and autumn; others, only in the autumn. When daylight decreases day by day in the fall, weasels replace their summer pelage of brown with one of white. They change again to a brown coat when daylight increases in the spring. This is true of the snowshoe rabbit, which has a brown summer pelage and a white winter one.

An armadillo's suit of armor. Some mammals have a thick outer covering to discourage predators.

Russ Kinne/PR



Altitude. When mammals such as sheep, dogs, and white rats go from low to high altitudes, their red blood cells increase in number. At sea level, sheep, for example, have 10,500,000 red blood cells per cubic millimeter of blood. At an elevation of nearly 5,000 meters, their red blood cells increase to 16,000,000. This increase is an adaptation for the high altitudes, where the amount of oxygen in the atmosphere is reduced. Since the red blood cells carry oxygen, more of them are needed in order to supply the body tissues with sufficient oxygen. The llama, vicuña, and viscacha (a rodent), which permanently live in the Andes at elevations of 3,700 to over 4,600 meters, have an even better adaptation. Their hemoglobin, the pigment of the red blood cells, has a much greater capacity for carrying oxygen than does the hemoglobin of lowland-living species.

Habitat. Certain mammals dig shelters in the soil. Others live entirely underground. The platypus, various marsupials,

Sometimes the best defense is a speedy gallop away from the scene. These zebras have a powerful kick and a nasty bite as well.

Pfeffer—Images et Textes

Bruce Coleman

Raccoons are omnivorous. With their nimble hands they can catch and "wash" all kinds of food. Raccoons are cousins of the bears.

many rodents and rabbits, armadillos, and carnivores, such as foxes and skunks, dig simple shelters in which to sleep, hide, and bring forth and care for their young. Voles, hamsters, and various ground squirrels, including woodchucks and chipmunks, store food and hibernate, during winter, in their burrows. The truly subterranean mammals such as the marsupial mole, the true moles, the mole rats, and the pocket gophers dig nesting chambers, chambers for storing food, connecting galleries, and galleries in which they hunt food. They are completely adapted for an underground life, having thick, short hair and strong, oversized digging claws on the front feet. Their eyes are minute or missing, and external ears are lacking or almost so. Moles hunt underground insects, insect larvae, and earthworms. The mole rats and gophers feed on plant roots and tubers.

Plants serve mammals in many important ways. Grassy clumps, patches of weeds, bushes, and the crowns of trees afford ideal places for small mammals to take shelter from the elements and escape the attack of carnivores and birds of prey. Kangaroos, deer, various antelopes, buffalo, and elephants find the forest a good refuge.

Vegetation attracts hordes of insects, which provide food for numerous small mammals, including opossums, shrews, hedgehogs, bats, civets, skunks, and certain ground squirrels and monkeys.

A number of mammals live in trees and only rarely descend to the ground. Among the most specialized of these animals are certain monkeys and apes. They have developed great dexterity with their hands and feet. The thumb and great toe can be opposed to the other fingers and toes of the hand and foot. This permits a very good grasp of tree branches. The hand and the wrist are exceptionally mobile, and the long arms can move in almost any direction because of the great freedom in the shoulder joint. Gibbons and spider monkeys are very good at swinging by their arms from branch to branch. Some South American monkeys, such as spider and howling monkeys, possess a *prehensile*, or grasping, *tail* as an additional means for climbing and remaining secure in the trees.

Tree squirrels live only where there are trees. They cling to a trunk or branch by their sharp claws. A sloth spends its life upside down in trees, using enlarged, hooklike claws to hang from a branch. It travels on the ground only with great difficulty.

Some mammals glide, sometimes for considerable distances, from tree to tree. This is true of the flying lemurs, flying squirrels, and the squirrel-like marsupials known as flying and gliding phalangers. All have a furry membrane along the sides of the body extending between the front and hind limbs. When gliding, the membrane is stretched so that the animals almost float through the air like parachutes.

Most strictly land-living, or terrestrial, mammals are capable of swimming. Certain mammals spend much or all of their time in water. They include the platypus, water opossum, water shrew, beaver, muskrat, water civet, and otter. These animals are usually sleek and have dense fur. Most have elongated, pointed snouts. The feet are usually completely or partially webbed. The tail is often flattened horizontally or from side to side.

The most completely aquatic mammals

are the seals, manatees, and whales. They have streamlined spindle-shaped, or torpedolike, bodies with extremely short necks and no external ears. The front limbs are converted into paddles, and, in the case of seals, the hind legs too. Whales and manatees lack hind legs but have broad, horizontally flattened tails. Some whales, such as the fast-swimming killer whales and dolphins, even possess a fleshy fin on the back.

Several factors permit the aquatic mammals to remain submerged for some time. For one thing, these animals renew the air in their lungs, when breathing at the surface, more completely than do terrestrial animals. In addition to the oxygen in the lungs, extra oxygen is taken up by blood that flows from the lungs into special networks of blood vessels. Once a dive is made, the heartbeat slows down. Blood continues to flow in the brain and other vital centers but is shut off from the rest of the body. Thus the oxygen of the blood is not quickly exhausted. A dive may be prolonged without the animal being forced to come to the surface for air.

DIFFERENT FOOD NEEDS

Plant-eaters. Plants serve as food for numerous mammals. These animals are adapted in various ways for a vegetarian diet. Fruit-eating bats, for instance, have flattened grinding teeth. Some bats even possess an elongated tongue for feeding on nectar. The monkeys and apes eat a considerable variety of foods; vegetation forms a good part of their diet. The stomachs of guerezas—monkeys of tropical Africa—are divided into a number of open sacs, which aid in digesting leafy food. The aquatic sea "cows" (manatee and dugong) are herbivorous mammals that use their lips to crop aquatic plants. These are digested in a complex stomach. Bears eat a good deal of plant food, including roots and berries.

S. C. Bisserot—Bruce Coleman Ltd.
de la Fosse Daviel—Images et Textes
C. Belinsky/PR

Top: cloven hooves and thick coats give these goats the advantage in high mountains. Middle: most horses are domesticated—bred for racing, riding, and draft work. There are still some wild ones left. Bottom: anteaters of the order Edentata have powerful digging claws and long snouts.

Y. Lanceau — Jacana

Some mammals are tougher than others. While many mammals are endangered species, the Norway rat continues to thrive—despite pest control.

Rodents and rabbits are well-known plant eaters. Their front teeth, or incisors, are formed like chisels and are used for gnawing. The molars are developed for grinding. Rabbits eat fresh, green food voraciously. Some of this is completely digested in the intestines. In this case the waste is excreted normally. Some of the green food, however, is fermented for a while in the *caecum,* which is a blind pouch off the large intestine. The food is then excreted, eaten again, and passed through the digestive tract a second time. More energy can be obtained from a given quantity of food as a result.

Rodents often have storage places for food. Hamsters, voles, squirrels, and kangaroo rats store various seeds, bulbs, tubers, roots, nuts, or mushrooms. The beaver provides itself with a winter supply of branches and trunks of poplar, aspen, cottonwood, and willow, from which it gnaws the bark. The material is submerged near the animal's lodge sufficiently deep in the water to prevent its being caught in the ice.

Among the most specialized of the herbivores are the kangaroos and hoofed mammals. Kangaroos have a single pair of lower incisor teeth with sharp inner edges, perfect for cutting grass. The horses and their kin crop grass and other vegetation with gripping incisors in the upper and lower jaws. Deer, cattle, and their relatives possess only lower incisors. These work against a horny pad on the upper jaw for cropping. The tongue helps bring food to the mouth. It is covered with horny projections. It is large, mobile, and pointed and can be considerably extended out of the mouth. The molar teeth of all these mammals have broad grinding surfaces. The molars of the elephant are immense. This animal collects plant food with its trunk.

In the digestive system of kangaroos, deer, cattle, and some other mammals, there is a chamber or sac in which bacteria break down the cellulose of plants so that the products can be used by the animal. Bacterial action takes place in the large intestine of horses. Deer, giraffes, antelopes, cattle, sheep, and goats all have a complex, four-chambered stomach. Food is received into the first two stomachs when it is initially swallowed; here bacteria reduce the food to a *cud* (pulp). This is brought back into the mouth for chewing. Later it is swallowed and further digested in the last two stomachs. Animals digesting food in this way are called *ruminants.*

Some whales, such as the blue whale, possess a series of sheets of *baleen*—a horny substance—hanging down from the roof of the mouth. The baleen is frayed along the inner edge. It strains out plankton from the water after the whale has engulfed a mouthful of water and animals.

The land-living carnivores are strong and quick-reacting animals. Some can deliver powerful blows with their sharply clawed front feet. Many are strongly muscled in the limbs, allowing for climbing, leaping, or the rapid pusuit of prey.

Marine carnivores, such as the seals, lack carnassial teeth but have simple, pointed teeth used for catching and holding fish. The walrus' tusks are modified canine teeth that root up bottom-living crustaceans and mollusks. These are ground by the walrus' broad, crushing cheek teeth.

Certain whales, such as porpoises, sperm whales, and killer whales, have simplified teeth, capable of grasping fish and squids or tearing apart the flesh of birds, seals, and other whales.

Insect eaters. Many mammals feed on insects. The winged mammals called bats catch insects while on the wing by opening the very large mouth. It is believed that the species that have a membrane between the hind legs may sometimes curve this membrane, in flight, so as to form a cup. The cup dips insects out of the air. The bat bends down its head, while still in flight, and eats its prey out of this pocket.

MEANS OF DEFENSE

Mammals can protect themselves from their natural enemies in various ways. One of the most obvious protective measures is to run away. Many mammals – the cheetah, for example – are very fast runners. Some – kangaroos and hares, for instance – have long hind legs that give them good speed in a bounding escape flight. The hoofed mammals have slender, elongated, running-type legs that lift the body high off the ground. The animals run on their toenails, which are modified into hoofs.

An escaping mammal, if pressed too closely by an attacker, may seek to defend itself. Various methods are employed. The anteaters and sloths lash out with their long, strong claws. Rodents and opossums bite their enemies. Hoofed mammals kick out with their feet, or use their tusks, horns, or antlers.

Sometimes, instead of running away, many mammals may freeze on the spot. This is common with young fawns. Their lack of movement and their dappled coat generally cause them to be overlooked by a predator. Hares will remain motionless until one comes close to them; then they bound away in a zigzag flight. The opossum "plays dead," lying limp with eyes closed and tongue hanging out of its partly opened mouth.

Many of the smaller mammals move about only at night or under the cover of vegetation or under fallen leaves and other debris of the forest floor. The large cud-chewing hoofed mammals come out into the open to feed rapidly.

Armadillos and pangolins are armored

Fievet – Jacana

The hippopotamus, which lives in and around the rivers of central Africa, is a member of the pig family. The head of this hippo may weigh about 1,000 kilograms.

with horny plates or scales. When danger threatens, they roll up so that only the protected surfaces of the body are exposed to an attacker. Hedgehogs, porcupines, and spiny anteaters are protected by hairs that are modified into sharp spines or quills.

Civets, mongooses, and skunks spray an attacker with an evil-smelling liquid – a secretion from modified sebaceous glands in the region of the anus.

Many mammals are patterned or colored in such a way that they blend well with the background. If they refrain from moving, it is usually all but impossible to make them out. For example, the white winter coat of many weasels, foxes, hares, and lemmings blends with the snow. Many desert mammals are pale buff or tawny, "melting in" beautifully with the desert soils.

SOCIAL LIFE

Apart from the relations between a mother mammal and her young, a host of social relations exist among the adults and young of a population. Among the most conspicuous of these is *dominance,* in which one individual ranks over one or more of its fellows. The most dominant animal eats first. It displays aggressive behavior toward its inferiors. In a given mammal population, male 1, say, dominates males 2, 3, and 4; male 2 dominates males 3 and 4; and male 3 dominates male 4. The same order may follow among females and among the young. The males dominate the females; the adults dominate the young.

Family groups are common among certain mammals. For example, the American beaver lives in a group consisting of two adults, the young of the current year, and often the young of the year before. When the young reach maturity they are driven away. Howler monkeys form clans consisting of several adult males, a greater number of females, and a variable number of young.

Fur seals and sea lions live in herds for the greater part of the year. During the breeding season, the adult males form harems of several females. At this time immature individuals and adult bulls that have not been able to gather any cows make up a separate group. A number of other species of seals live in herds but never form harems. The males and females breed at random.

Elephants, members of the horse family, hippopotamuses, many of the piglike mammals, giraffes, vicuñas, a majority of the deer, and most of the cattle, antelopes, sheep, and goats are social creatures. Generally the males associate with one or several females only during mating time. After breeding, the males abandon their mates or harems and establish herds of males only or else lead a solitary life. The females and young collect in a herd of their own, "controlled" by an adult female leader.

Certain mammals are not social. The chipmunk is intolerant of any others of its species. Only for mating do the sexes come together, and immediately afterward the male and female become antagonistic toward one another. The female associates with her young only as long as they remain in the nest. Bears, too, join company only to mate. During the rest of the year, the males live by themselves. The females, however, are followed by their cubs for a fairly long time.

Most mammals do not roam about at random. They restrict their explorations and food-searching activities to a home *range.* The mammal's lodging place – nest, burrow, thicket, or other shelter – is within this range. There are also various places where the animal can attend to its comfort. For example, deer include in their home range wallowing places in which to take mud baths. The badger has a particular spot for sunning itself. Zebras, bears, and bison use termite nests or trees as "rubbing posts." In general, the size of the range of a particular mammal depends upon the amount of food available for its needs. Tigers, lions, wolves, and bears have an extensive home range. At the other extreme there is the woolly opossum, which may stay in a single tree for several months of the year.

Though many mammals spend the whole of their lives within a home range, some species migrate – that is, they travel from one area to another and back again.

CLASSIFICATION

There are 22 orders of living mammals in the class Mammalia. The monotremes, belonging to the first order, are reptilelike and only remotely related to the rest of the mammals. The animals in the next four orders are the marsupials. The animals grouped together in the remaining 17 orders are placental mammals. Following is a brief account of the different orders.

Monotremata: duck-billed platypus, spiny anteaters. The monotremes are like reptiles in certain features of their skeleton and their egg-laying habit. The platypus, of Australia and Tasmania, has a flattened bill, flattened tail, and webbed feet. Spiny anteaters, which possess a mixture of spines and hair on the back, have elongated faces and tongues adapted for eating ants. Spiny anteaters live in Australia and New Guinea.

Marsupicarnivora: carnivorous or omnivorous marsupials, including opossums, pouched mice, native cats, Tasmanian devil, Tasmanian wolf, banded anteater, and pouched moles.

Peramelina: insectivorous marsupials, the bandicoots of Australasia.

Paucituberculata: shrewlike marsupials, the opossum rats of western South America.

Diprotodontia: Australian herbivorous marsupials, including phalangers, cuscuses, gliders, brush-tailed opossums, honey opossums, kangaroos, wallabies, koalas, wombats.

Insectivora: solenodon, tenrecs, golden mole, hedgehogs, elephant shrews, shrews, moles. These are small, secretive, mostly ground-living and nocturnal animals with elongated snouts. They feed on insects or are omnivorous.

Dermoptera: colugos, or flying lemurs. The colugos, from Indonesia and the Philippines, are much like insectivores except that they are adapted for gliding. Broad, furry skin folds extend, at the side of the body, between the front and hind legs and onto the tail; when the colugo stretches its legs, the animal becomes a furry kite, gliding long distances from one tree to another. Colugos are the size of squirrels. They have foxlike faces. They eat leaves, flowers, and fruit. When sleeping, they hang upside down from a branch, with all four feet grasping it.

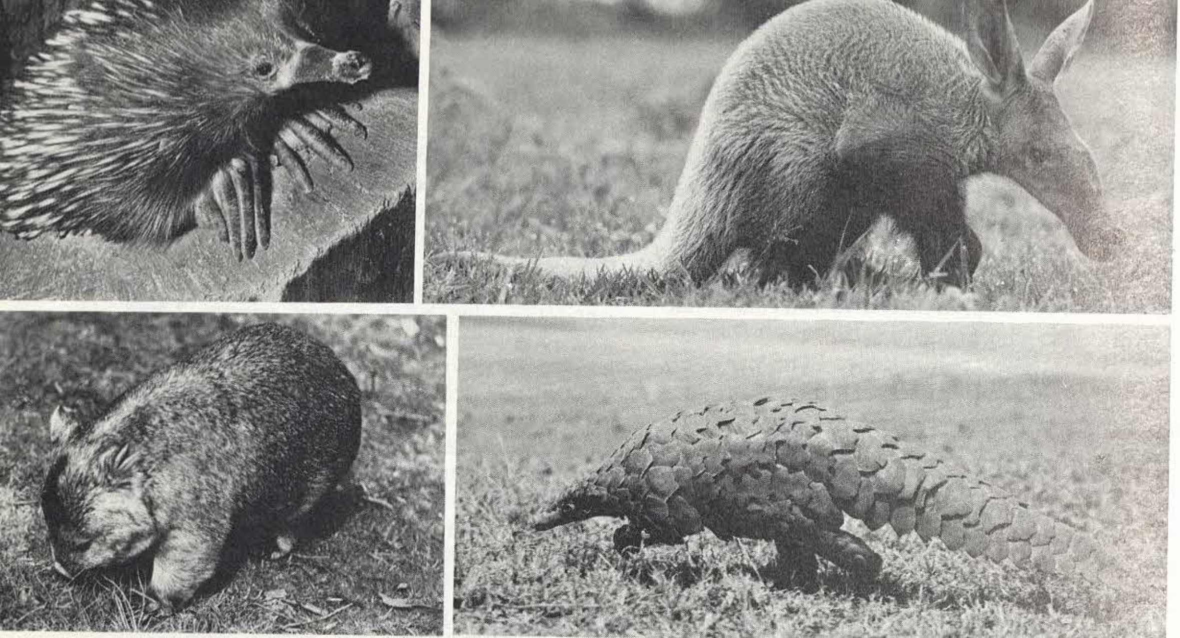
Chiroptera: bats. These are the only mammals that can truly fly, doing so by flapping their wings. The bats are essentially insectivores. They have greatly elongated bones in the front limbs and fingers for supporting the wing membranes. The hind legs are weak, making the animals almost helpless on the ground. They cannot walk, but can crawl and climb. When resting, bats hang upside down clutching a support with the clawed toes of the hind feet.

Bats are found on all continents except Antarctica, and most oceanic islands. Large fruit-eating bats live in the tropics and subtropics of the Old World. The largest of these, called flying foxes, have a 1½-meter wingspan. Most of the smaller species feed mainly on insects, which they catch on the wing. Several bats catch fish by hovering over the water's surface and seizing the quarry with their hind feet. Vampire bats, of Central and South America, feed on blood. They pierce the skin of large mammals with special pointed incisor teeth and lap the blood oozing from the small wound.

Edentata: anteaters, sloths, armadillos. The edentates are close relatives of the insectivores but are specialized for climbing and digging. Well-developed long and stout claws arm the feet. The diet is somewhat restricted. Hence, the teeth are reduced in number and simplified. Additional joints in the backbone make edentates very strong. The brain is comparatively small. Edentates occur in South and Central America. One species, the nine-banded armadillo, is found in the southern United States.

The anteaters have an elongated, tube-shaped snout, which is used to probe anthills and temite nests. They lack teeth. Sloths, which have a round head and a short face, are leaf eaters. They have no front teeth. The back teeth are simplified and lack a covering of enamel. Armadillos are covered by armor. Shields of small, flat bones in the skin, topped by horny plates, cover the shoulder and hip areas. Between these bony shields are bands of horny plates giving flexibility to the back. The top of the head and the tail are also protected by horny plates. As with sloths, there are no front teeth. The teeth along the sides of the jaw are simple pegs without enamel. Armadillos feed on insects, carrion, and whatever else they can find on the ground. They are excellent burrowers.

Pholidota: pangolins, or scaly anteaters. The pangolins are like anteaters but have evolved independently from an insectivore ancestor. They have an elongated snout, large claws, and no teeth. Flattened, leaflike, horny scales cover the back and sides of the body from the nose to the tip of the long tail. These scales, which are composed of fused hairs, overlap like the scales of a pine cone. Pangolins live in tropical Africa and Asia; they are nocturnal, and several species can climb trees very well.



Arthur Ambler, Audubon/PR; Jen and Des Bartlett/PR; Australian News and Information Bureau; Jen and Des Bartlett/PR

Top left: the spiny anteater is an egg-laying mammal. Bottom left: the wombat, a marsupial, feeds on plants. Top right: the termite-eating aardvark. Bottom right: the toothless pangolin is covered with overlapping scales.

Primates: tree shrews, lemurs, lorises, galagos, tarsiers, New World monkeys, Old World monkeys, apes, man. The primates are closely related to the insectivores and apparently directly evolved from them. They have five digits, with nails instead of claws, on each hand and foot. The diet is usually restricted.

The primates surpass all other animals in mental development. The brain—especially the cerebral hemispheres—is large. After birth, the young primate takes an unusually long time to develop and depends on parental guidance during much of its immature life. Family life is well established.

Rodentia: mountain beaver, tree squirrels, ground squirrels (including marmots, woodchucks, prairie dogs, chipmunks), flying squirrels, pocket gophers, pocket mice, kangaroo rats, beaver, New World mice (including wood, pack, and cotton rats), hamsters, lemmings, voles (including muskrats, meadow mice), antelope rats, mole rats, bamboo rats, Old World rats and mice (introduced everywhere and including house rats and mice), African tree mice, dormice, jumping mice, jerboas, porcupines, guinea pigs, capybaras, pacas, chinchillas, coypus, and many others. There are more species of rodents than all other species of mammals combined.

Rodents have just four front teeth that are chisellike and adapted for gnawing.

Rodents have a great capacity for reproduction. This and their generally small size account for their great success in the world. They occur almost everywhere.

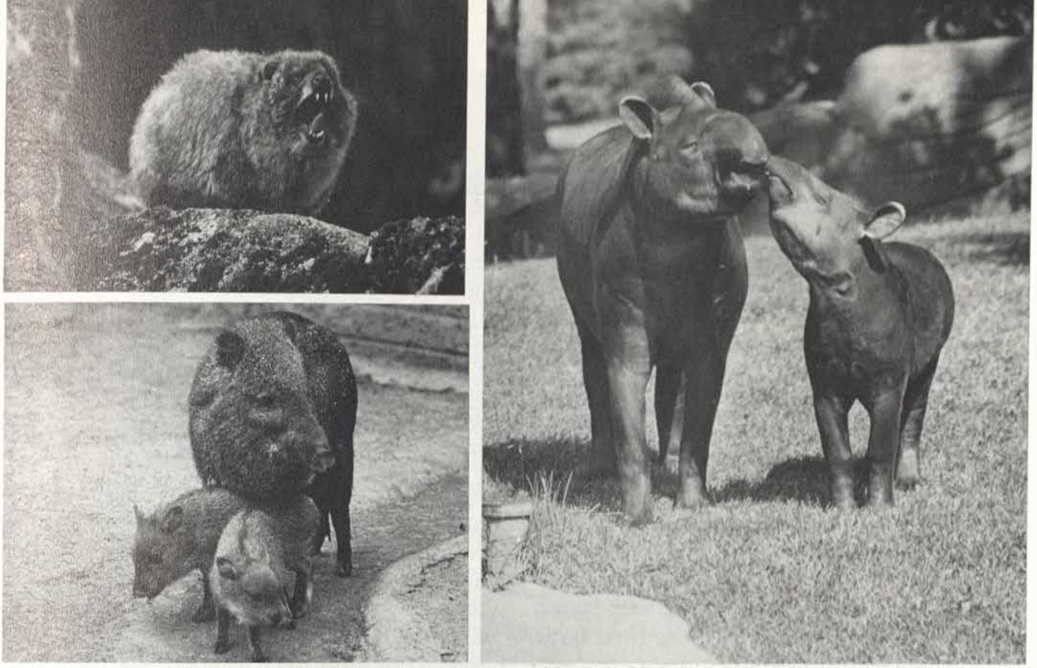
Lagomorpha: pikas, or conies, hares, rabbits. These superficially resemble rodents but are not closely related to them. They have chisellike front teeth, but, unlike rodents, the lagomorphs have a second, smaller pair of incisor teeth in the upper jaw. The cheek teeth cut vegetable food rather than grind or crush it.

Mysticeta: baleen, or whalebone, whales, including rorqual or finback whale, humpbacked whales, blue whales, right whales, gray whales. They feed by filtering krill through the baleen plates that hang down from their upper jaws.

Odontoceta: toothed whales, including river dolphins, beaked whales, sperm whales, beluga whales, narwhals, dolphins, killer whales, and porpoises. They feed using their teeth and have a single blowhole.

Carnivora: dogs, wolves, foxes, hunting dogs, bears, raccoons, pandas, weasels (including ferrets, minks, wolverines, badgers, skunks, otters), civets, mongooses, hyenas, cats (from the lion to the domestic tabby), eared seals (including fur seals, sea lions), walrus, true seals (including common, harbor, and harp seals, elephant seals). These lithe, powerful, generally clawed mammals are highly specialized for hunting medium-sized to large prey.

Tubulidentata: aardvarks. These short-legged, nocturnal African mammals are the size of a small pig. The head is long and pulled out into an elongated, tubular snout. Long, slender



Jen and Des Bartlett/PR; Gordon S. Smith, Audubon/PR; Jeanne White, Audubon/PR

Top left: a yawning hyrax, a rabbitlike mammal distantly related to the elephant. Bottom left: collared peccaries are hoofed, with even-numbered toes. Right: tapir and young. Tapirs are also hoofed but have odd-numbered toes.

ears surmount the head. The tail is heavy and tapering. With its powerful front legs and sharp, flat nails, the aardvark digs burrows and tears up the nests of termites upon which it feeds. The cheek teeth are small cylinders lacking enamel. There are no incisors or canine teeth.

Proboscidea: elephants. These are the largest of land mammals. The flexible muscular trunk is formed by the elongation of the nose and upper lip. The trunk's tip is a sensitive grasping organ. Tusks are protruding upper incisor teeth, which continue to grow long after adulthood is reached.

Hyracoidea: hyraxes. The hyraxes, of Africa and Asia Minor, resemble rabbits somewhat in appearance and habit, though they have short ears and some live in trees.

Sirenia: dugong (or sea cow), manatees. The naked-skinned sirenians are related to the hoofed mammals but are modified for an aquatic mode of life. The body is streamlined, and the head is low, ending in a blunt, bristly snout. The brain is small. Manatees live along the Atlantic coasts of Africa and the tropical Americas, sometimes going far up the larger rivers. The dugong inhabits the coasts of the Red Sea, Indian Ocean, and western Pacific.

Perissodactyla: horses (including asses and zebras), tapirs, rhinoceroses. These are the hoofed mammals with odd-numbered toes. In these animals the axis of the foot passes through the middle, or third, toe, which is best developed. The horse has one functional toe on each foot; the tapirs and rhinos, three. The toes end in hoofs. Horses have elongated limbs specialized for swift running; the tapir's legs and feet are short and stocky. The odd-toed hoofed mammals have a full set of incisor teeth for cropping plants.

Wild horses occur in Asia and Africa, but domestic forms are worldwide in distribution. The rhinoceroses, of Africa and Asia, carry horns that are formed of clumped masses of hair without a bony core. Tapirs, which live in Indonesia and Central and South America, have the nose elongated into a short, flexible trunk.

Artiodactyla: pigs (including water hog, wart hog, babirussa, peccaries), hippopotamuses, camels (including llama, vicuña), chevrotains, deer (including musk deer, muntjak, fallow deer, elk, moose, caribou), giraffe, pronghorn, cattlelike mammals, antelopelike mammals, goatlike mammals. These are the hoofed animals with even-numbered toes. There are either two or four functional toes, usually bearing hoofs, on each foot.

Some forms—called *ruminants*—such as deer, giraffes, cattle and their kin—have the stomach divided into four compartments. The horns of cattle and antelopes are formed of a horny material over a bony core. Deer antlers are bony outgrowths, which are shed periodically. The even-toed hoofed mammals are native to all continents except Australia, where domestic forms have been introduced, and Antarctica.

THE EGG-LAYING MAMMALS

What has a beak like a duck, lays eggs like a reptile, and has fur like a beaver? A duck-billed platypus.

It is very hard to believe that a duck-billed platypus is a mammal. After all, everyone know that mammals do not lay eggs. Or do they?

Zoologists have studied this strange animal's anatomy and physiology and have decided that the duck-billed platypus is indeed a mammal. It is a warm-blooded, fur-bearing animal that has functional mammary glands. And, if one egg-laying mammal is not enough for you, then have another – a spiny anteater.

EVOLUTION

The duck-billed platypus and the spiny anteater are members of the subclass of mammals called the Prototheria, or "first mammals." There is only one order – the Monotremata, or the monotremes. The monotremes are divided into two families: the spiny anteater family Tachyglossidae and the duck-billed platypus family Ornithorhynchidae. Both of these families are found only in Australia, New Guinea, and Tasmania.

A duck-billed platypus. This primitive mammal looks like a collection of parts from other animals. It makes its living in creeks and rivers.
Australian News and Information Service

Not much is known about the evolution of this primitive order of mammals. Fossils of an ancestral form of these animals have been found only in the areas where the existing animals are found. Some authorities believe that the only reason these animals survive today is because of the isolation of the regions in which they live. They have very little competition from other, more advanced mammals.

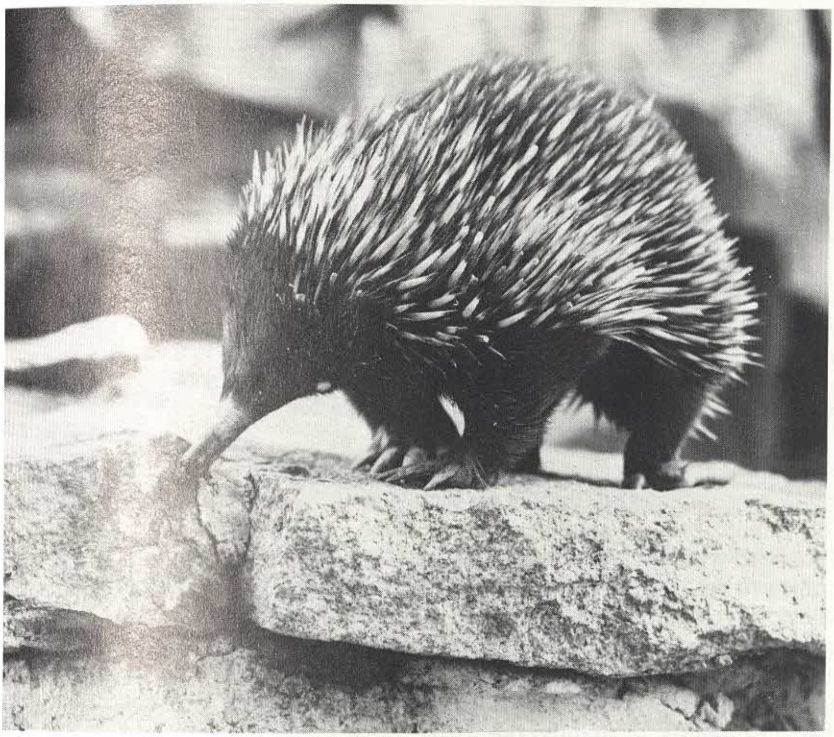
Zoologists think that the line leading to the present-day monotremes must have split off very early from the main line of mammalian evolution. They theorize that some years ago, mammal-like reptiles known as therapsids evolved into two lines. One line led to the prototheria, and the other to the rest of the mammals.

MANY REPTILIAN FEATURES

Monotremes have some decidedly reptilian features. The most striking similarities involve the reproductive system. In monotremes, as in reptiles, the reproductive, urinary, and digestive tracts all merge in a common chamber called the cloaca, which opens to the outside. The sex organ of the male monotreme has a structure somewhat similar to that of the penis of a reptile. The female monotreme lays eggs. These eggs have a large yolk and are covered with a leathery shell – still other reptilian features.

The structure of the monotreme's pectoral, or shoulder, girdle and the presence of scalelike structures on the skin of the platypus and spiny anteater also show their close relationship to reptiles.

Monotremes do, though, have characteristic mammalian features. They are warm-blooded – that is, their body temperature is not totally dependent on their environment but rather is regulated by complex



Australian News and Information Service

The spiny anteater. The animal lives on ants and termites caught by the long snout. This egg layer carries its young in a pouch.

internal mechanisms. They do have hair or fur, and the females do have mammary glands. The structure of the heart, circulatory system, and brain of the monotremes also all reveal similarities with corresponding structures of other mammals.

SPINY ANTEATER

The spiny anteater is stout and compact with a short tail. It is about 60 centimeters long and is covered with protective spines. It has a long snout that looks like a beak. A long, narrow tongue slips through the snout to pick up the animal's favorite food—ants and termites. The spiny anteater has very long, hard claws and can dig very quickly with these claws.

The female spiny anteater lays her eggs and then places them in an abdominal pouch. She carries them around for about ten days until the young hatch. The young remain in the pouch until the spines develop on their skin—about ten weeks later. While they are in the pouch, they are fed by milk that oozes out of the mammary gland. The young do not suckle, but lick up the milk as it trickles down the hair near the gland. The spiny anteater is long-lived. It may live over fifty years.

THE DUCK-BILLED PLATYPUS

The duck-billed platypus is about 60 centimeters long, 15 centimeters of which make up a flattened tail. The platypus has very thick fur and a broad, flat beak.

The platypus is specialized for finding food in the creeks and rivers in which it lives. The webbed feet help the animal swim underwater in search of food. It feels for food along the bottom with its highly sensitive duck-bill. It does not rely on sighting food: its small eyes are weak. The platypus has no teeth, but the mouth has horny ridges that help break and grind the food. The platypus lives on insect larvae, crustaceans, snails, and an occasional fish. The animal eats a very large amount of food.

The female platypus usually lays two eggs. Unlike the spiny anteater, she has no brood pouch. The eggs are incubated in a nest.

The male platypus is the only truly venomous mammal known. This animal has rear ankle joints with hollow spurs which are connected to venom glands. Males can drive these spurs into an enemy, releasing venom into their victim. Such a platypus attack is quite painful.

KANGAROOS AND OTHER POUCHED MAMMALS

The curious creatures known as marsupials, or pouched mammals, make up an unusual collection of animals. Their mode of reproduction in particular differs radically from that of most mammals. Most mammals, greatly as they may differ from one another in size and habits, reproduce in much the same way. The female produces a tiny egg cell that is fertilized within her body, and after a time comes to rest in her womb, or uterus. As the egg develops, membranes are formed around it. One of these membranes fuses with the wall of the uterus so that a firm connection is made between the developing young, or embryo, and its mother. This connection, which is called a *placenta*, is richly supplied with blood vessels. It serves as a passageway, by which nourishment and oxygen are passed from the mother to the embryo. After a certain length of time, varying with different species, the then well-developed young is forced from the womb and is born —that is, leaves the mother's body. The mammals that reproduce in this way are sometimes called *placental mammals*, or *placentals*.

The female pouched mammal brings forth its young in a different fashion. It produces an egg with a much larger supply of yolk than that of a typical placental egg. This egg is fertilized within the body of the female, but no placenta is developed. (The rabbitlike bandicoot of Australia is an exceptional case. A primitive and only partly developed placenta is formed within its body.)

The embryo in the womb of the female pouched mammal is nourished on the yolk of the original egg cell. A nutritive solution, called *uterine milk*, in which the embryo is bathed, also furnishes a certain amount of food material. The embryo does not remain long in the mother's womb. It is forced out of the body at a very immature stage of development. The young of the opossum leaves the mother's body eight days after the fertilization of the egg. The young of the kangaroo remains in the womb for only 39 days.

When the baby marsupial emerges from its mother's body, it is an almost shapeless bit of flesh. Little more than a centimeter in length, it is blind and naked. No external ears show. The hind legs and tail are mere buds. Surprisingly enough, however, the front legs are equipped with large clawed hands, whose nerve centers are well developed. By means of these hands the baby crawls up the mother's belly and finds its way to the pouch, or *marsupium*, which is located there. This pouch gave rise to the name *marsupials*.

DEVELOPMENT IN THE POUCH

The baby animal finds shelter and warmth in the marsupium. Within it are the mother's *teats*, through which the little animal draws milk. The baby fastens on one of the *nipples* with its mouth, so that the nipple is thrust far down into its throat. The upper and lower lips of the little animal grow together at the corners around the nipple, and the nipple itself swells. As a result the baby is securely fastened to its source of nourishment. Thus enclosed within its mother's pouch, the young marsupial feeds and grows. It leaves its snug shelter only when it is fairly well developed and capable of eating and digesting other kinds of food besides its mother's milk. But it does not leave its pouch sanctuary permanently, even at this stage of its development. As we shall see, it hops back into the pouch quite frequently, particularly if danger threatens.

EVOLUTION OF MARSUPIALS

In order to understand the relationship between the marsupials and the placental

Pizzey—Bruce Coleman Ltd.

Kangaroos are the largest marsupials. They can bound across the Australian plains at speeds of more than 50 kilometers per hour.

animals, we must go back to the early history of the mammal group. The earliest mammals, which were descended from mammallike reptiles, were in all likelihood small creatures that lived in trees. From these early animals various mammal types evolved. One type, which reproduced its kind by laying eggs, succeeded in maintaining itself. Today, this group of egg-laying mammals is represented by the platypus and the spiny anteater of Australia. Two other groups of mammals managed to survive, and became the ancestors of our modern placentals and marsupials.

The early marsupials were opossumlike. They had small brains, but they were far more intelligent than any of the reptiles that were then living. Gradually marsupials spread throughout the tropical and temperate regions of the world. In the course of time they came into competition with the placentals and almost invariably succumbed to their rivals. Gradually the marsupials were driven out of Eurasia, Africa, and North America. They continued to thrive in South America and Australia. In the course of time, however, great numbers of highly developed placental mammals pushed their way into the South American continent. The marsupials could not withstand this onslaught, and most of them perished. Today a few scattered species, including the opossums, are the only surviving representatives in the two Americas of what was once a flourishing population of marsupials of many different kinds.

The marsupials of Australia fared much better than their American cousins. About 50,000,000 years ago, Australia became isolated from the rest of the world. The marsupials dominated this vast land, and they increased their numbers and evolved into many different types.

As is quite frequently the case with an actively evolving group, some of the Australian marsupials became giants. There was a lionlike marsupial species, a three meter tall kangaroo, and a rhinoceros-sized wombat.

The disappearance of marsupial giants like these is a puzzling problem. Changes in climate, decreasing food supply, the spread of poisonous plants, the outbreak of disease—all these factors may have been involved. Other marsupials of Australasia, however, were more successful than their giant relatives and have survived to modern times. They exploited the opportunities at hand and so spread out into a variety of habitats.

In modern times, however, some marsupials of Australia, particularly the smaller species, have seriously decreased in numbers. Some species have become extinct. The primary causes seem to be loss of habitat. Agricultural and stock-raising activities have drastically taken away good grazing land and introduced animals have destroyed marsupials. Recent reports, however, indicate that some marsupials, particularly kangaroos, are in no danger and are in fact increasing in numbers.

TYPES OF MARSUPIALS

The marsupials evolved into three major types. One group became carnivorous. There were catlike marsupials, today called *native cats;* wolflike creatures, represented by the modern Tasmanian wolf; and a wolverinelike animal, from which the modern Tasmanian devil descended. Another group was insectivorous. It included marsupial anteaters with long snouts, marsupial moles with reduced eyes and well developed fore limbs, and pouched mice, resembling the shrews of other parts of the world. A third group, including phalangers, kangaroos, wallabies, wombats, and koalas, became herbivorous.

The phalangers were tree dwellers. They had prehensile tails, by which they could cling to branches. Some even developed extensions of skin along the sides of their bodies, so that they could soar from one treetop to the next. Kangaroos and wallabies became ground-dwelling plant eaters. They hopped about on their hind legs. The wombats became tailless, stout-bodied animals with rodentlike grinding teeth.

KANGAROOS

Our survey of the Australasian marsupials begins with the kangaroo family Macropodidae. It is a varied group that includes various sized members from the kangaroos, which stand nearly two meters, to the musk kangaroo, which is only rat-size. Wallaroos and wallabies also belong to this family. These marsupials are all hopping animals. The front legs are relatively short and undeveloped. The hind legs are enlarged and muscular. The hind feet are elongated. The fourth toe is the longest. The short second and third toes are fused together. There is no first toe. All have front teeth specialized for clipping grasses, shoots, and leaves. The molar teeth have ridges on their crowns for grinding this vegetable food.

The kangaroos (genus *Macropus*) are large, powerfully built animals capable of bounding at speeds of more than 50 kilometers per hour for short distances. When moving at a slow pace they spring a dis-

The wombat is a ground-dwelling marsupial. It uses its clawed front feet and rodentlike teeth to excavate burrows and tunnels.

Jacques Six

S.C.E.R.T., West Bengal
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tance of about two meters at a single bound. As they increase their speed they may make leaps of eight meters. While they are moving rapidly, the heavy, thick tail is held out almost horizontally to counterbalance the forward thrust of the body. The tail is also used as a rudder to swing the body when the animal wants to make a turn at full speed. When the kangaroo grazes, its arched body rests on all fours. To move, the animal pushes its tail against the ground, at the same time lifting its hind legs and swinging them forward.

The red kangaroos are plains dwellers, whereas the great grey kangaroos inhabit brushy country and open forests. Both are gracefully built animals with exceedingly long hind legs and thick but tapering tails.

Kangaroos usually mate once a year and have one or, rarely, two young. They can however produce more than one litter a year, sometimes nursing two generations at once while yet another generation is in an early stage in the womb.

The only help the mother seems to give her tiny offspring in finding the pouch is to lick a path in her fur from the opening of the birth canal to the entrance of the pouch. If the infant embryo loses its way in her fur or drops to the ground, she does not help it. The time taken for the young to make the journey to the pouch is judged to be about fifteen minutes with the great grey kangaroo and from five to thirty minutes with the red kangaroo. Once the weaned young leaves the maternal pouch, it does not stray far from its mother, jumping back into its retreat at the first sign of danger from fox, dingo, or eagle. If a female, carrying a young one, is chased by dogs or a hunter on horseback, she will dump her offspring from the pouch. Whether she does this to lighten her load or allow the young to escape is not known. It is said that if she survives the chase, she returns to where the young was dropped.

Wallaroos are stockily built kangaroos that live in rocky regions of the mountains. They have roughened soles on their hind feet which prevent slipping as they leap from rock to rock.

Collet/PR

Male kangaroo resting. When the kangaroo decides to move, it will push off the ground with its strong tail.

Tree kangaroos of the genus *Dendrolagus* differ somewhat from the other members of the kangaroo family because of their tree-dwelling habits. The hind foot is comparatively shorter and broader. Though not a grasping organ, it has curved, sharp claws and roughened soles. The forelimbs are more equal in length to the hind, and the broad hands serve admirably in climbing. The tail is long and slender but not prehensile. Tree kangaroos ascend trees to sleep, feed on leaves and fruit, and escape from predators. Compact of body, they climb agilely, using the tail as a prop and balancer. Usually they descend a tree tail first, but if hard pressed they leap downward five to ten meters to another tree or to the ground, where they easily alight on all fours.

Rat kangaroos are diminutive members (subfamily Potoroinae) of the kangaroo family. They are agile, ground-dwelling marsupials equipped with prehensile tails. They feed on grasses, fungi, tubers, and refuse. Rat kangaroos dig burrows or shallow depressions sheltered by bushes or a fallen tree. Some rat kangaroos dwell together in colonies, but others live in pairs or are solitary.

Musk kangaroos, genus *Hypsiprymnodon,* seem to be intermediate between the kangaroos and the phalangers, or "possums." The hind legs are not so disproportionately large; the tail is opossumlike—hairless and scaly. Unlike the kangaroos,

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The female kangaroo carries her young in her pouch. They seek her pouch when frightened.

the musk kangaroo possesses a big toe; this is not opposable to the other toes.

WALLABIES

Wallabies are kangaroolike in habits and appearance but are of medium and small size. The smaller ones dig ground burrows that have an open exit some distance from the entrance. When frightened, they dash for the burrow from some lookout point close by the entrance. Larger wallabies seek refuge in ground hollows scooped out under bushes. The brush wallabies *(Protemnodon)* are large, gracefully built, and often distinctly marked and handsomely colored. Scrub wallabies, or padamelons *(Thylogale),* are smaller and are thick-tailed. They live in dense scrub areas and have tunnellike runways through the heavy undergrowth. Rock wallabies *(Petrogale)* are skilled in climbing and bounding over the rocks in mountainous areas. Their foot pads, like those of the wallaroos, are roughened, giving traction on slippery surfaces. Nail-tailed wallabies *(Onychogalea)* get their name from the horny projection at the tip of the tail. The hare wallabies *(Lagorchestes)* are solitary animals, much like hares in habits and appearance.

PHALANGERS

The phalangers (family Phalangeridae) are cat-size or smaller marsupials, specialized for tree living. They have sturdy limbs and curved claws. Unlike the kangaroos, they possess a first hind toe. This toe is opposable to the other toes and is used for gripping. The tail is either prehensile or, as with the gliding phalangers, is extravagantly furred, almost featherlike, and serves as a rudder. The phalanger's head is somewhat squirrellike. The well-formed maternal pouch opens toward the front. The second and third toes are joined together but have separate claws. This arrangement serves as a comb to preen the fur. Phalangers are night-roaming and feed on insects and vegetation.

The honey mouse, or honey possum *(Tarsipes),* is a tiny phalanger with an elongated, trunklike muzzle, which can be thrust deeply into flowers for nectar and pollen. The pygmy possums *(Cercaërtus)* are small phalangers that hibernate in cold weather. Other noteworthy phalangers include striped possums *(Dactylopsila),* ring-tailed phalangers *(Pseudocheirus),* common possums *(Trichosurus),* and cuscuses *(Phalanger),* which have small ears and a prehensile tail with a naked and scaly tip. Gliding phalangers belong to three separate groups, but all possess gliding membranes along the sides of the body.

KOALAS

The koala, or native bear *(Phascolarctos),* appears to be related to the phalangers, but it differs from them by having only a rudimentary tail and well-developed cheek pouches. The maternal pouch faces to the rear instead of forward. The koala is completely arboreal, climbing by means of its strong limbs and powerful claws. This robust marsupial, which has a woolly coat, feeds exclusively on the leaves of only a few species of eucalyptus. Koalas usually breed only once every two years. One young (sometimes two) is born. When the young abandons the pouch it climbs to the mother's back. She carries the cub until it is almost full grown. A curious habit of the female koala is to manufacture a pap, or soft food, of eucalyptus leaves in her body at the time when the young one is being weaned. The cub eats this pap, which contains no excrement, from the mother's anal opening. Apparently this food greatly speeds up the young's growth.

WOMBATS

The wombats are ground-dwelling marsupials, being heavy-bodied with short, stout legs. They are excellent burrowers and will sometimes excavate an underground tunnel extending nearly 30 meters in length. Their front feet carry powerful digging claws. Their rodentlike front teeth gnaw through any roots that obstruct their tunneling activities. The tail is a mere nubbin, and the head large. These nocturnal animals live alone, pairing only at mating time. Grasses, fungi, and the inner bark of some trees and shrubs make up their diet. The common wombat *(Phascolomis)* is distinguished by having short, rounded ears, coarse hair, and a naked area on the muzzle. It is fairly large, measuring over one meter. The hairy-nosed wombat *(Lasiorhinus)* is smaller. It has soft, silky fur and longer, tapering ears.

BANDICOOTS

The bandicoots (family Peramelidae) are ratlike or rabbitlike marsupials having pointed muzzles and large ears. Their hind limbs are fairly long, with the second and third toes fused. The front limbs are small. These curious little animals are both herbivorous and carnivorous.

INSECT-EATING MARSUPIALS

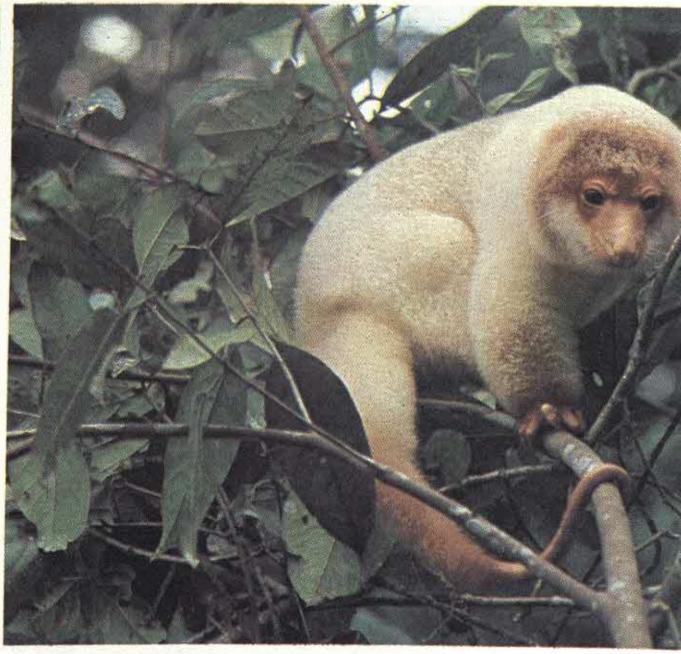
The marsupial mole *(Notorcytes)* is outwardly completely molelike. Its body is small and compact, its muzzle cone-shaped. The tiny ears lie buried in the short fur of the head, the legs are short and stocky, the fingers have enlarged digging nails and the tail is a rudiment. The non-molelike feature, of course, is the pouch, which opens to the rear. This little marsupial plows through the desert sand more than five centimeters below the surface, coming above ground at intervals. It feeds on ants and probably other insects and worms.

The koala is the teddy bear of Australia. Adapted for arboreal life, it eats only eucalyptus leaves.

Holton/PR

The cuscus is a member of the phalanger family. The prehensile tail helps it in its arboreal habitat.

Fiels/PR



Russ Kinne/PR

The Tasmanian devil is a small, but powerful, carnivorous marsupial.

Another insect eater, the banded anteater *(Myrmecobius),* feeds on ants, termites, and their eggs and larvae. This marsupial is rat-size and has a long, bushy tail, prominent ears, and a pointed muzzle. Its tongue, by which it captures insect prey, is long and thin. The female marsupial anteater lacks a pouch. The young are protected only by her fur as they cling firmly to her nipples.

The pouched mice (subfamily Phascogalinae) are also insectivorous. They are similar to mice but have numerous needlelike teeth and more tapering muzzles. Some species live in trees, while others are ground dwelling.

CARNIVOROUS MARSUPIALS

The native cats *(Dasyurus)* supplement their insect diet with birds and birds' eggs. These white-spotted carnivorous marsupials are weasel- or martenlike and are mostly nocturnal and tree-living.

The Tasmanian devil *(Sarcophilus)* is a fairly small though powerful flesh eater. It can climb but usually lives in rocky areas, where it hunts for the smaller wallabies, rat kangaroos, rats, birds, and lizards. This animal is short-legged, with a large head and strong jaws. Like the marsupial wolf, it is confined to Tasmania.

The Tasmanian wolf *(Thylacinus)* lives only in the most inaccessible parts of its island home. The largest marsupial carnivore, it is strikingly doglike, running on its toes more than does any other marsupial. It has piercing canine teeth, flesh-shearing premolar teeth, and bone-crushing molars. The animal is nocturnal, hunting alone or in pairs for other marsupials, rats, and birds.

NEW WORLD MARSUPIALS—OPOSSUMS

Aside from the pouched mammals of Australia and neighboring areas, the only other marsupials inhabit the New World. These include the South American opossum rats *(Caenolestes),* which are ground-living and have no pouches, and the arboreal woolly, murine, and common opossums (family Didelphidae) of South, Central, and North America. Most possess naked, prehensile tails. The females bear many young at one time. Those that lack the pouch carry their young at first attached to the nipples. Later the infants climb to the mother's back, wrapping their tails around hers.

One species of opossum, the yapock, or water opossum, seems to be the only marsupial specialized for an aquatic life. It is found along rivers and other bodies of water from Guatemala to southern Brazil. Above, it is ashy gray, with broad black cross bands. It is whitish below. This aquatic marsupial is about three-quarters of a meter long. It has webbed feet, a marsupial pouch, and a naked, prehensile tail. The yapock feeds upon aquatic animals.

The most familiar of the opossums is the Virginian, or common, opossum *(Didelphis virginiana).* It ranges from New York to Florida and from the Atlantic coast to the Great Lakes and south to Texas. It is about as large as a cat. Its tail is some 40 centimeters long. It has a long pointed snout, sharp teeth, prominent ears, a long, almost naked prehensile tail, and a marsupial pouch. It has long, grizzled gray external hairs and short, whitish underfur. Opossums are nearly omnivorous. The opossum den is comfortably bedded with leaves and dry grass. There, litters of five to fifteen young are born once or twice a year.

THE INSECT EATERS

The group of small mammals that specialize in eating insects includes the hedgehogs, shrews, moles, tenrecs, and solenodons. These *insectivores*, or insect eaters, as they are called, are widely distributed in the temperate and tropical portions of the Old and New Worlds. Hedgehogs are found in Europe, Asia, and Africa. Moles and shrews are also found in those continents as well as in North America. The tailless tenrec dwells on Madagascar. The ratlike solenodon lives in Haiti and Cuba. Australia and the oceanic islands have no members of this group. South America has practically none; the only representatives of the insect eaters in that continent are a small number of shrews.

GENERAL CHARACTERISTICS

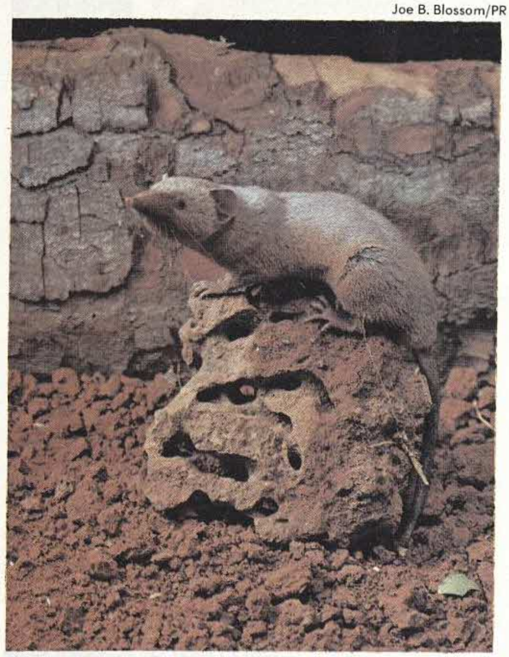
The insectivores are not seen as frequently as other mammals. They are shy and retiring animals. They are mostly active at night, frequenting places where abundant growths of vegetation serve to attract numerous insects. For the most part they are small-bodied creatures with elongated and mobile snouts and small eyes and ears. They possess musk, or scent, glands, from which a strong-smelling substance is secreted. Their toes are armed with very strong claws. Certain species of insectivores use these claws as tools for burrowing into the earth.

The burrowing types of insect eaters, such as the moles, excavate a vast network of tunnels in the ground. The shrews and the hedgehogs, on the other hand, live above ground, though shrews sometimes use the tunnels made by mice. The African otter shrews, the water shrews, and the water moles are particularly well fitted for an aquatic type of life. Most of the insectivores supplement their staple diet of insects with worms, snails, lizards, and small birds. Shrews often devour mice. Otter shrews feed upon fish. Hedgehogs also consume fruit.

Though many animals, such as birds,

The insectivores, or insect eaters, are a group of small, shy mammals. Top: a musk shrew, useful in ridding a home of insect pests. Middle: a shrew mouse. Bottom: hedgehogs—common in the Old World.

Joe B. Blossom/PR



Bruce Coleman

Bruce Coleman

fish, bats, frogs, snakes, and other mammals eat insects, they are not all insectivores. The true insectivore is a mammal distinguished by its peculiar teeth. These have the shearlike action of the typical carnivore, as opposed to the grinding action found in most other animals. In addition, the insectivore's teeth are furnished with sharp projections enabling the animal to seize and pierce the body of insects. Nearly all members of the order possess a long, narrow, mobile muzzle. The brain shows several primitive characteristics. These primitive characteristics are large olfactory bulbs (extensions of the brain concerned with the sense of smell), few folded surfaces, and an underdeveloped cerebrum. The cerebrum is well developed in the higher mammals, such as the apes. In man and other higher mammals this portion of the brain is concerned with the thinking process.

GROUP HISTORY

Though the insectivores make up only a small part of the present-day mammalian population, they are particularly interesting because they show us what some of the first mammals were like. Between 160,000,000 and 230,000,000 years ago, certain reptiles gradually evolved into the mammalian type of animal. The first mammals were quite small. They ate either insects or flesh and they lived in trees. Their small size and tree-dwelling habits undoubtedly helped them escape the attention of the formidable flesh-eating dinosaurs. From this early mammalian stock several types of mammals evolved. One branch developed into the egg-laying mammals, such as the duck-billed platypus; another, into the pouch-bearing animals; still another, into the true insectivores. The bats, which still feed on insects, were an early offshoot from these insectivores.

The insectivores of today seem to have departed but little from their ancestors. It is

John H. Gerard, Audubon/PR

John H. Gerard, Audubon/PR

Moles are a common yard pest. They prefer open areas and often damage lawns, golf courses, and cultivated areas. The mole (upper left) is consuming a favorite prey—an earthworm—that it probably found while digging extensive tunnels (left).

true that the hedgehogs now have a coat of bristling spines and that the moles have gone underground to live, but their skeletal structure, teeth, and small brain show typically primitive characteristics. Perhaps the shrews have changed least of all. They are still unspecialized, mouselike creatures. The tree shrews, which have a larger brain than their relatives, were generally considered to represent a link between the insectivores and the primates, which include the lemurs, the monkeys, apes, and man. The tree shrews, also known as tupaias, are now included in the order of primates.

CLASSIFICATION

It has been extremely difficult for zoologists to classify the insectivores. The taxonomist, or one who classifies living things according to their natural order, looks for similarity of anatomical features when he tries to fit animals into a logical classification. When the taxonomist deals with the insectivores, he finds that some types have retained many ancient, specialized features, while others have been profoundly modified through the ages.

According to the modern classification, the eight surviving families, arranged according to increasing specialization, are the Solenodontidae (including the solenodon of the West Indies); the Tenrecidae (great tenrec, aquatic tenrec, rice tenrec, otter shrew); Chrysochloridae (golden mole of South Africa); the Erinaceidae (hedgehog, moonrat, gymnura); the Macroscelididae (elephant shrew); the Soricidae (common shrew, pygmy shrew, short-tailed shrew, or "mole" shrew, muck shrew, web-footed shrew); the Talpidae (desman, "shrew" mole, eared shrew mole, star-nosed mole, all the American moles); and the Tupaiidae (tree shrews).

The ancestor of the insectivores is believed to have been a hedgehog type. Its teeth and bones have been found in fossil deposits that date back to the Upper Cretaceous period, some 60 million years ago. Considering the fact that they survived for such a long period of time, the insectivores must have been astonishingly successful in adapting themselves to changes in climate and to the predacious, or hunting, habits of carnivorous animals, their greatest enemies.

This phenomenon of *adaptation* is very important for the modern theory of evolution. An adaptation may be defined as a characteristic that is advantageous to an animal in the particular surroundings in which it lives. Sight is a distinct advantage for all animals living on the earth or in the air. Genetic factors can cause hereditary poor sight in animals. The blind animal would have to develop other senses such as smell and touch to survive. In an underground environment, it would even have the advantage over a sighted animal, which needs vision to orient itself. It is therefore not surprising that the insectivore known as the mole, an animal with small, weak eyes but keen sense of touch, has survived. Regardless of its shortcomings in vision, it has evaded its enemies and found food.

TRUE MOLES

In adapting to their environment, moles chose to lead lives of underground burrowers. The form of the mole body shows adjustments made for this mode of living. The mole's head is conical in shape. There is no distinct neck, and the body is in the form of a compact cylinder. The eyes are minute with the power to discriminate only between light and darkness. Some moles even have the eyes covered with a thin layer of skin. External ears are lacking. The soft, thick fur is like velvet, lying smoothly in whatever way it is pressed, keeping friction at a minimum as the mole burrows through the soil. The powerful front feet are its digging tools. These feet are very broad and are equipped with stout, strong claws. The front legs of some species are set so that the soles of the feet face outward. The feet, fleshy nose, and hairy or naked tail are sensitive organs of touch. The mole's sense of smell is keener than its vision. The sense of touch is best developed and is used to locate prey.

Moles inhabit much of the world's north temperate region but are absent in the Southern Hemisphere. North America has several species. The eastern mole is a

John H. Gerard, Audubon/PR

The eastern mole is a moderate-sized animal with a naked tail. It is a common resident in lawns and gardens in the eastern part of the United States.

moderate-sized animal, about 15 centimeters long, with a short, naked tail. It commonly occurs in low meadows, gardens, and lawns in the eastern half of the United States. The Pacific mole and related species live along the Pacific ocean coast from Baja California to northern Washington. They are similar to the eastern mole but are larger and have a slightly hairy tail. The hairy-tailed mole is a small animal, whose tail is decidedly hairy. It is confined to the northeastern states and southeastern Canada. A unique North American mole is the star-nosed mole, which has a disk of short, fleshy tentacles at the end of its nose. It lives in the eastern states and southeastern Canada. The common European mole represents the mole family in the Old World. Its habitat ranges from Great Britain and France to Japan.

THEY DIG TUNNELS

Moles require a fairly moist, loamy soil which is easily worked. Their burrows must be humid, since these creatures cannot live long in a dry atmosphere. They prefer open terrain, such as lawns, low meadows, and gently sloping hillsides. The star-nosed mole, however, chooses the damp soil and grassy swamps near streams or lakes, while the hairy-tailed mole likes upland wooded areas.

Moles excavate two types of tunnels. There are temporary channels that lie close to the surface, forcing the soil into ridges. There are permanent galleries that run through the soil about one-third of a meter or so below the ground. In the tunnels near the surface, the moles hunt for food. The mole literally swims through the soil at an amazing speed. The soil is not removed but merely pressed aside by the mole's body as it forces its way through.

The deeper galleries are more carefully constructed and serve as passageways to the hunting ground and to the mole's nesting chamber. Using first one front foot and then the other, the mole loosens a bit of soil and passes it back along the side of the body, kicking it to the rear with its hind feet. When a quantity of loosened soil has accumulated, the mole then pushes it along the tunnel to an outlet at the surface. This makes the characteristic molehill. The little insectivore is careful to keep the outlet plugged with dirt when it is not in use.

The mole has a keen sense of direction. A mole digs at about the same level below the surface whether the ground forms a ridge or a hollow. The eastern mole digs tunnels at the rate of about 3½ meters per hour. During a mole's lifetime, an extensive network of these tunnels is excavated. Some tunnels may be used in common by dozens of moles living in the same area.

UNDERGROUND NESTS

The mole's nesting chamber, or fortress, is excavated about one-third of a meter below the surface, under a good-sized mound. If the animal lives close to water, the chamber is located above the water level. Several galleries lead from the upper part of the chamber and form a network of channels around it. It is believed that these may aid in giving proper aeration to the chamber. At the base of the fortress another gallery is excavated. This serves to drain the nesting site of any excess moisture and gives the mole an emergency exit in case of danger. The nest itself is composed of leaves and grass. During the breeding season, female moles construct a similar but smaller nesting chamber in which to have their young. Moles are usually solitary creatures. They defend their fortress and its approaches and their hunting territory against intruders.

Mating occurs during the early spring and occasionally in the fall. The female carries the young in her womb from four to six weeks, depending upon the species. From two to six offspring are produced. The young develop quickly and are ready to take care of themselves when but six or eight weeks old. The eastern mole may live about three years, barring accidents.

ACTIVE LIVES

Since moles are extremely active creatures, they require a great deal of food to keep themselves alive. It has been estimated that a mole will eat its weight in food every day. Earthworms, beetle larvae, cutworms, adult beetles, and snails form the principal food. Apparently, when there is an abundance of earthworms, moles store them to be eaten later. The mole bites the worm at the front end. This immobilizes the prey but does not kill it.

Moles spend the greater part of their lives underground. Occasionally they come to the surface in order to hunt for prey, to find water, and to obtain grass and leaves for the nest. They can swim, sometimes crossing small rivers. The star-nosed mole is an accomplished swimmer and diver. It has even been observed swimming under ice during the winter.

WATER MOLES AND SHREW MOLES

The active swimmers known as water moles, or desmans, which live in Spain, northern Europe, and the Soviet Union, are related to the true moles. These animals have webbed hind feet, a vertically flattened tail, and long, oily guard hairs that protect the skin and thick fur from water. The elongated, tubular snout forms a proboscis. Desmans construct their nesting chambers in river banks. They prey on small aquatic animals of all kinds, including fish.

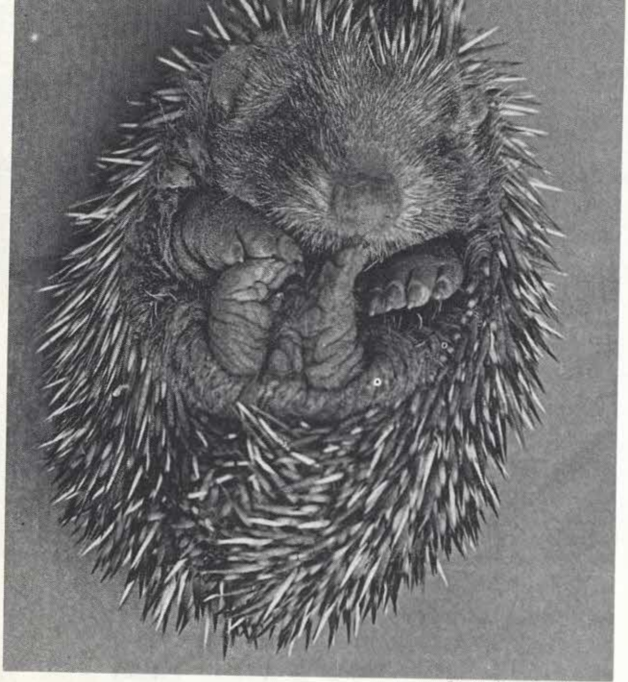
The tiny shrew mole is another insectivore related to the moles. It has features of both the shrews and the moles. For instance, its face is long like that of a shrew, but its naked muzzle is molelike. Its moderately broad, stoutly clawed front feet are larger than those of a shrew but not so well developed as those of a mole. Shrew moles live in the humid coastal areas of the northwestern United States. A similar species, the eared shrew mole, occurs in Japan. These insectivores live partly underground, partly on the surface.

HEDGEHOGS

Hedgehogs and their kin comprise a family living entirely in the Old World. The common hedgehog has a small rounded body, short legs and tail, and a sharply tapering muzzle. Its back and sides are covered with hairs modified into sharp but unbarbed spines, or quills. Coarse hairs cover the legs, under parts, and face. It inhabits Europe and Asia from Great Britain to Korea. Closely related species live in northern and eastern Africa. Southern Asia is the home of two rather curious relatives of the hedgehog, the moonrat and the gymnura. These are longer-bodied animals with long, pointed muzzles and moderately long tails. They lack spines.

When approached by a predator, the hedgehog rolls into a ball, tucking its head and feet into the center. The erect spines form a formidable defense against attack. This is not a completely efficient defense, however, for weasels, owls, vultures, and foxes sometimes made a meal of the hedgehog. The moonrat has an odor peculiarly like that of onions. This may be offensive to certain predators.

The hedgehog is, for the most part, nocturnal, spending the day in any place that affords warmth and dryness, such as a



Eric Hosking, Audubon/PR

Hedgehogs are found only in Europe, Asia, and Africa. When faced with danger, a hedgehog rolls into a ball. The quills on its back and spine provide a fine defense.

hollow log, a burrow in an embankment, or a den among rocks. It feeds on insects, worms, slugs, birds' eggs, frogs, and snakes. In hunting prey, the hedgehog will sometimes take to water, swimming fairly well. It will cross small rivers when pursued. During the winter, it hibernates in a snug retreat. At this time its body temperature may fall to 10° Celsius.

Usually hedgehogs breed twice a year. The gestation period lasts from five to seven weeks, and the number of offspring, which are covered with soft, white spines, averages from four to six. A nest of leaves in the shelter of a tree's roots or some hidden burrow serves as a nursery. Here the young remain until a month old. Then they follow the mother in her wanderings.

The gymnura, or rat shrew, is the closest living relative of the hedgehog. Rat shrew describes the external characteristics of this animal, but its teeth and its internal structure show that it is closely allied to the hedgehog. The gymnura is found in Burma, the Malay Archipelago, the Philippines, and parts of China. There are several species, some as big as good-sized rats, others as small as mice. All are purely insectivorous. The discovery of fossil remains of an extinct genus of gymnura in France has been cited as evidence of the similarity between the fauna of Europe in prehistoric times and that of the present-day Malay Archipelago.

SHREWS

The most numerous and widely distributed of all the insectivores are the shrews. The common shrew, or shrew mouse, found in Europe, Asia, and North America, is about the size of a mouse and somewhat resembles that animal, particularly in the shape of its body, feet, and tail. But it is distinguished from the mouse by its muzzle, which projects far beyond the lip. The common shrew feeds upon insects and their larvae and inhabits dry places, making a nest of various kinds of leaves and grasses. The young, numbering from five to seven, are born in the spring. Common shrews are very voracious, sometimes killing and devouring one another.

The pygmy shrew is even smaller than the common shrew. Rarely more than seven or eight centimeters in length, this tiny animal is the smallest mammal of the North American continent.

The short-tailed, or mole, shrew is the best-known species in the eastern United States. It is about 10 centimeters long, with a hairy tail measuring two and one-half centimeters. It remains quite active in the winter and is sometimes found burrowing in the snow. At this season of the year it feeds largely on beechnuts as well as insect pupae and larvae. At least one genus of short-tailed shrews produces a venom in its submaxillary glands. The venom is probably used for killing mice, but it is powerful enough to produce toxic symptoms in humans. Some other shrews may also produce venom.

The jumping shrews are also called elephant shrews because of the trunklike extension of the snout. They are ground animals and move by leaps, after the fashion of the kangaroo. The jumping shrews are entirely restricted to Africa. There are many species of these interesting animals. Some haunt the thick undergrowth, while others dwell in stony wastes where clefts and crannies in the rocks offer a secure haven during the day.

China has an aquatic shrew that is more highly specialized than any of its relatives—the web-footed shrew. The soles of its feet are provided with disklike pads. These pads enable the animal to grip securely the surface of smooth stones and rock as it seeks its food in a riverbed.

The musk shrew of India and Africa is remarkable for the strong, musky odor that emanates from glands situated on the sides of the body. Though it leaves an offensive musky trail, it is generally tolerated in the houses it enters, because it eats insects.

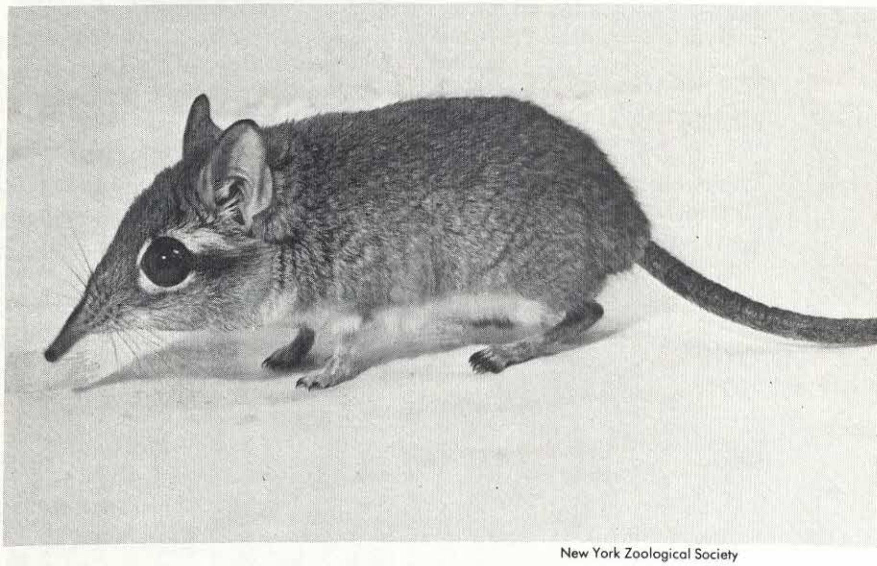
TENRECS AND SOLENODONS

Among the most fascinating of the insect-eaters are the tenrecs and the solenodons, which are closely related. The former are natives of the island of Madagascar. The latter are found in the West Indies. The existence of these closely allied animals in such widely separated areas points to ancient land connections that have vanished under the seas.

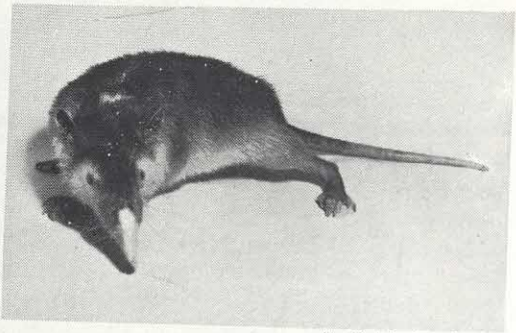
The great tenrec is the most fearsome beast of the tenrec group. Tailless, it attains a length of about 40 centimeters and considerable girth. It possesses formidable teeth and can inflict a serious bite. Its diet

Leonard Lee Rue III, Audubon/PR

Top: the common, or masked shrew, is found in Europe, Asia, and North America. Bottom: the elephant shrew, or jumping shrew, lives in Africa. Note the trunklike extension of the muzzle.



New York Zoological Society



New York Zoological Society

The solenodon is an inhabitant of Haiti.

consists almost exclusively of earthworms. It hunts this prey only during the night. To defend itself against its enemies, the tenrec has developed a formidable coat of armor, consisting of bristles and spines. This animal hibernates like the European hedgehog, and it lives in burrows, which it excavates by means of its strong claws. Unlike the hedgehog, however, the great tenrec does not roll itself up into a ball-like form for defense.

One species of tenrec has become aquatic. Another, the rice tenrec, carries its search for insects beneath rice roots to such lengths as to become a serious pest—more so than the insect pests upon which it feeds. Tenrecs rank among the most prolific of all mammals: as many as 21 offspring at one birth have been recorded. The flesh of these animals, especially before they hibernate, is valuable to the natives of Madagascar.

The solenodons, found only in Haiti and Cuba, have long snouts and tails and large ears. The body of the solenodon is hairy. By way of contrast, the tail is naked.

The otter shrew of West Africa finds a place among the insectivores because of the insectivorous characteristic of its teeth. The muzzle is broad—not pointed, after the fashion of other insectivores. This expert swimmer's habits—particularly its skill in catching fish—suggests the otter rather than the shrew.

TREE SHREWS

Once called the most primitive living primate, the tree shrew (family Tupaiidae) is now classified with the insectivores. The tree shrew, however, does have greater brain development than other insectivores, and its toes and thumbs are mobile enough to function as grasping organs. Tree shrews look like squirrels but have more pointed muzzles. Their fingers and toes are clawed. They live in trees, feeding on insects, fruits, leaves, and birds' eggs. Tree shrews are native to India and Southeast Asia.

Jane Burton/PR

The shrew family has several highly specialized aquatic members. This aquatic shrew searches for food along the riverbed.

HARES, RABBITS, AND PIKAS

Did you know that a jack rabbit really isn't a rabbit at all? It is a hare. All those different kinds of pet shop bunnies—did you know that most of them are derived from a single type of European rabbit? And pikas—you may not have ever heard of them, and yet they are closely related to rabbits.

AN ORDER UNTO THEMSELVES

Rabbits, hares, and pikas make up the order Lagomorphia, or "rabbit-bodied animals". These animals were once classified as rodents, and they are like rodents in having incisors, or gnawing teeth, that grow throughout their lifetime. But there are important differences between rodents and lagomorphs, and lagomorphs are now believed to be more closely related to the ungulates, or hoofed animals, than they are to rodents.

HARES AND RABBITS

Rabbits and hares make up the family Leporidae.

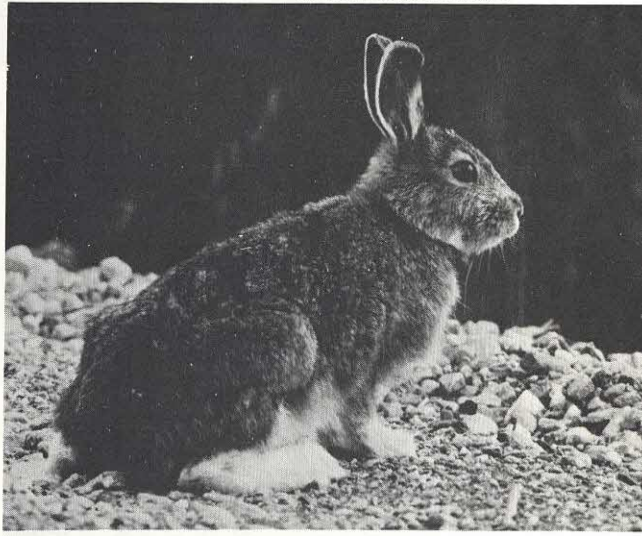
The hares and rabbits look very much alike but differ in some important respects. The young of the rabbit are born, blind and hairless, in underground burrows. The hare is born above ground in an open nest and has hair and vision from birth. The true hare averages something like 60 centimeters in length. The ears are about 20 centimeters long. The tail appears quite short, but this is partly because much of it is hidden in the fluffy fur of the belly. The true rabbit is somewhat smaller than the true hare. It averages 45 centimeters in length and from one to three kilograms in weight.

Both rabbits and hares have conspicuously long, powerful hind legs. Their hopping gait leaves a very distinctive track. In front are the two large prints, side by side, made by the hind paws. Slightly to the rear, one behind the other, are the smaller prints of the front legs, which are used more for self-defense and balance than for propulsion. For short distances, the powerful hind legs of the rabbit enable it to travel at speeds up to 70 kilometers per hour.

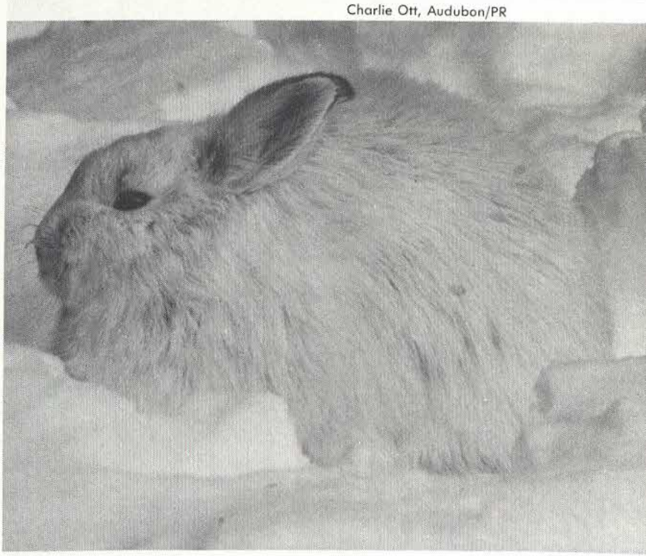
Rabbits and hares are pure herbivores in the wild. During the summer, hares and rabbits graze on grass, clover, and plants

The snowshoe rabbit, or varying hare, changes its coloration with the seasons. In summer the hare has a dark pelt (top) that helps it blend with the brush and rocks. In winter (bottom) the hare's white coat blends with the snow.

Phyllis McCutcheon Mithassel/PR



Charlie Ott, Audubon/PR

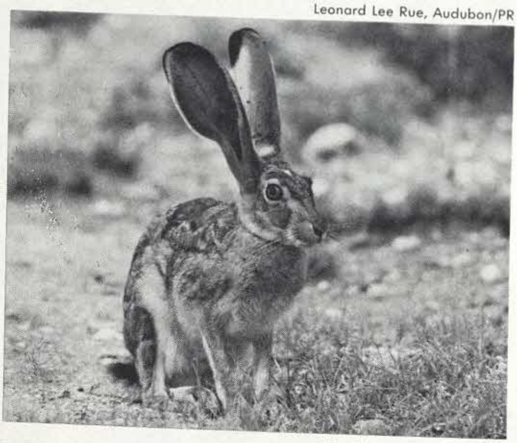


such as dandelions. During the winter they browse on bark, twigs, dry brush, and seeds. They also have an unusual digestive feature that helps them retain nutrients. These animals excrete semi-digested food, together with regular fecal material. The semi-digested food, called stomach pellets, is then re-eaten. It undergoes a second digestion, and valuable vitamins are retrieved from it.

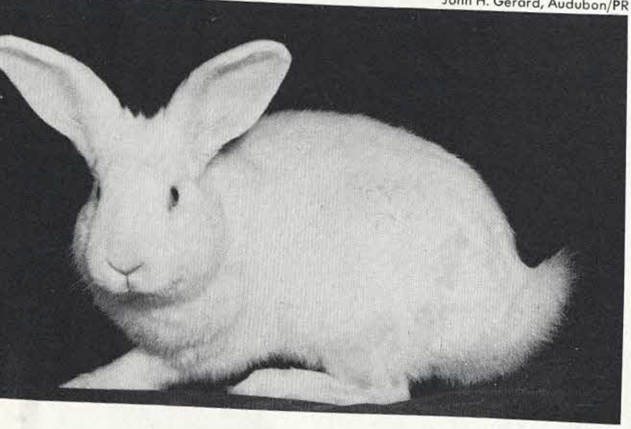
Rabbits and hares are well-known for their reproductive capabilities. Female rabbits and hares ovulate just after copulation. This practically ensures fertilization. In hares, there is a second unusual feature of the reproductive system: the female can carry two separate sets of offspring, each in its own stage of development. This is possible because hares have a two-horned uterus, and fertilization in one horn does not prevent ovulation and fertilization from occurring with subsequent offspring development in the other horn. This phenomenon is called *superfetation*. It is rare, but it does occur often enough.

Top: the black-tailed, or California, jack rabbit is really a hare. It is undesirable in some agricultural areas. Bottom: the New Zealand white domestic rabbit is derived from Old World rabbit stock.

Leonard Lee Rue, Audubon/PR



John H. Gerard, Audubon/PR



The Old World rabbit. The true rabbit is native to Europe. It is now found wild in Australia, although it was completely unknown there until it was introduced by Europeans. Having no long-standing natural enemies, the rabbit prospered in that huge island-continent. It did such damage to crops that foxes were introduced to control it. Although they did reduce the number of rabbits, the foxes themselves soon became a major pest.

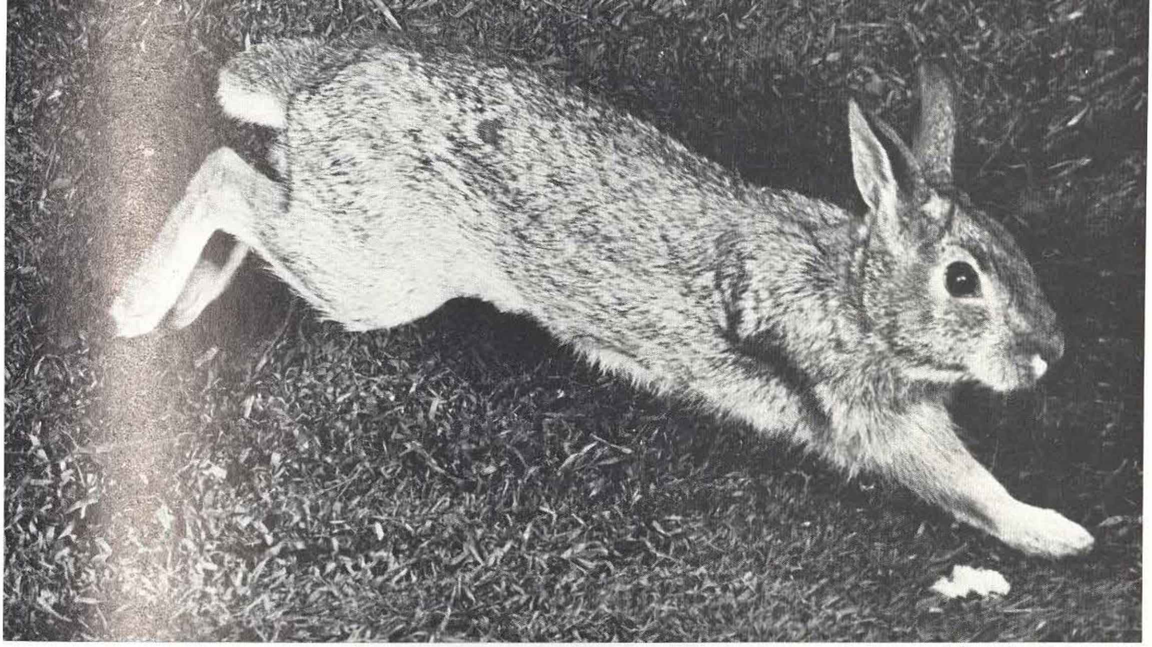
The common domestic breeds of rabbits are derived from the Old World rabbit. When crossed with the wild-type, the offspring show a broad range of characteristics.

True hares. True hares inhabit North America, Africa, Europe, and Asia. The European hare is probably the most well-known of the true hares. Because of its popularity as a game animal, it has been introduced in areas outside continental Europe. Hares do not usually migrate, but under unusual conditions—mainly, a scarcity of food—they will migrate in large groups.

The animals commonly called rabbits in North America are really hares.

Jack rabbits abound in the western part of North America. They are generally about 60 centimeters long and have prominent ears. They are a serious pest in many areas. The black-tailed, or California, jack rabbit is responsible for more crop damage than any other hare in North America.

Among the other large hares of the Western Hemisphere are the snowshoe rabbit and the arctic hare. The snowshoe rabbit, or varying hare, as it is also called, wears a brown coat during the summer. This changes to white during the winter months. The name "snowshoe" is derived from the fact that a heavy coat of hair develops on the foot during the winter months and forms a sort of snowshoe. The arctic



G. Ronald Austing, Audubon/PR

The cottontail shows features of both hares and rabbits. It closely resembles the true rabbit, but its young are born in nests, as are the hare's.

hare, largest of all hares, lives farther north and keeps its white fur all year round.

Cottontails. The cottontail occurs in great numbers in North America. It has both harelike and rabbitlike characteristics. It looks very much like a true rabbit. Its young, like those of the rabbit, are hairless and blind at birth. However, they are not born underground but in nests, as are the hares. Cottontails thrive in brush and along the fringes of various cultivated areas.

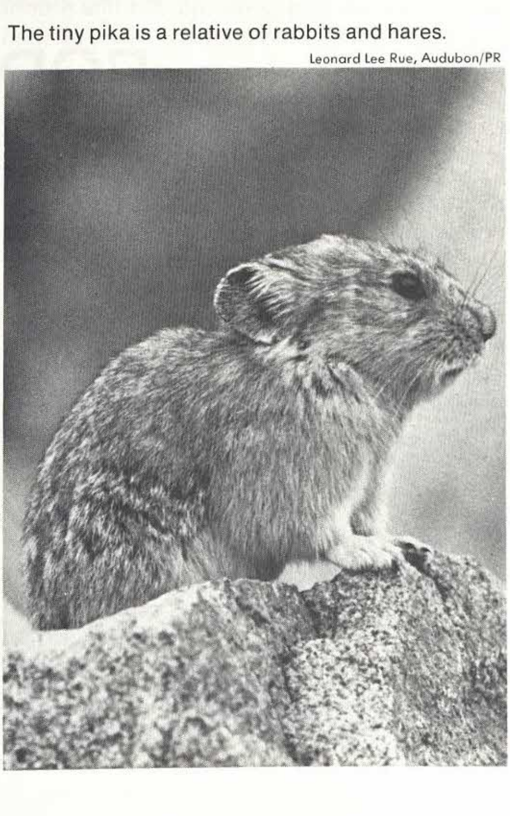
PIKAS

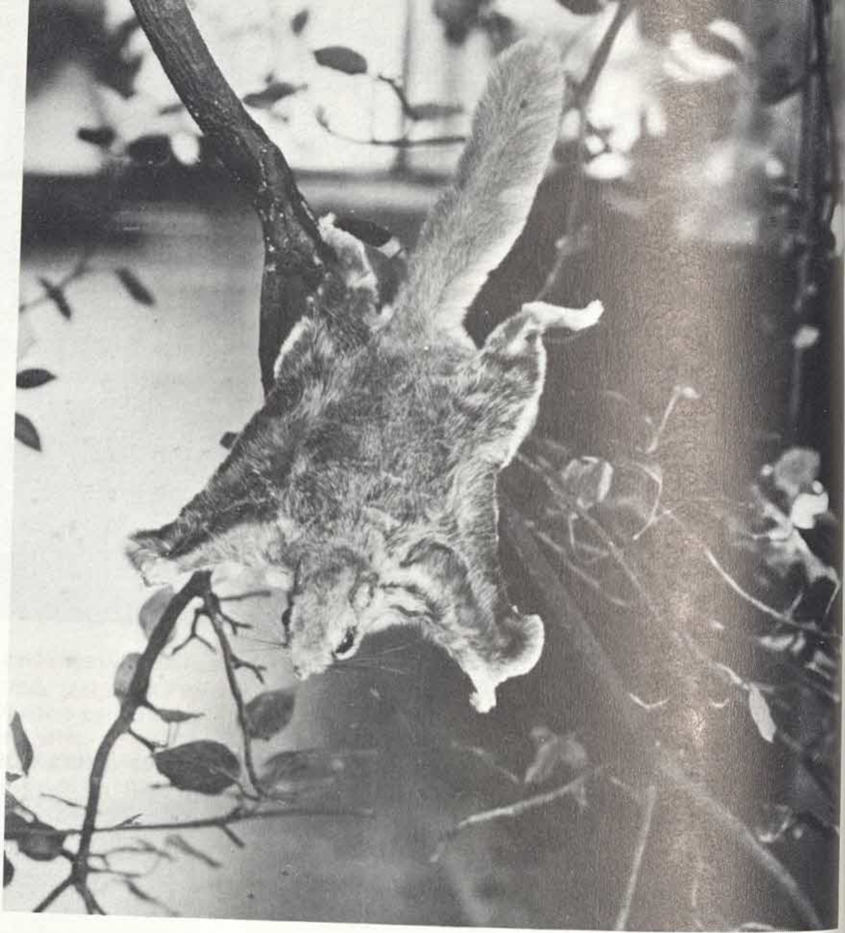
The pika (family Ochotonidae) looks very much like the rabbit or hare, except that its ears are shorter and it is tailless. It is very much smaller, too, averaging about 15 centimeters in length when fully grown. Unlike other lagomorphs, it lives high up in the mountains, where it makes its den in rocky crevices.

Although its shrill, bleating call is frequently heard in elevated regions, the animal itself is hard to find. Its coloration makes it blend into the background. When it moves, the motion is so quick that it simply disappears from one spot and then appears motionless at another (or so it is claimed by naturalists who have observed it). Since spring in the mountains comes late, the first litters are not born until May. Other litters continue to arrive until the month of September. In North America, the pika is found from the Rocky Moutains westward. In Europe and Asia, it is widely distributed east of the Ural mountains.

The tiny pika is a relative of rabbits and hares.

Leonard Lee Rue, Audubon/PR





Rodents can occupy a number of habitats. Right: a flying squirrel that can glide from branch to branch. Far right: a ground squirrel that usually lives in a burrow.

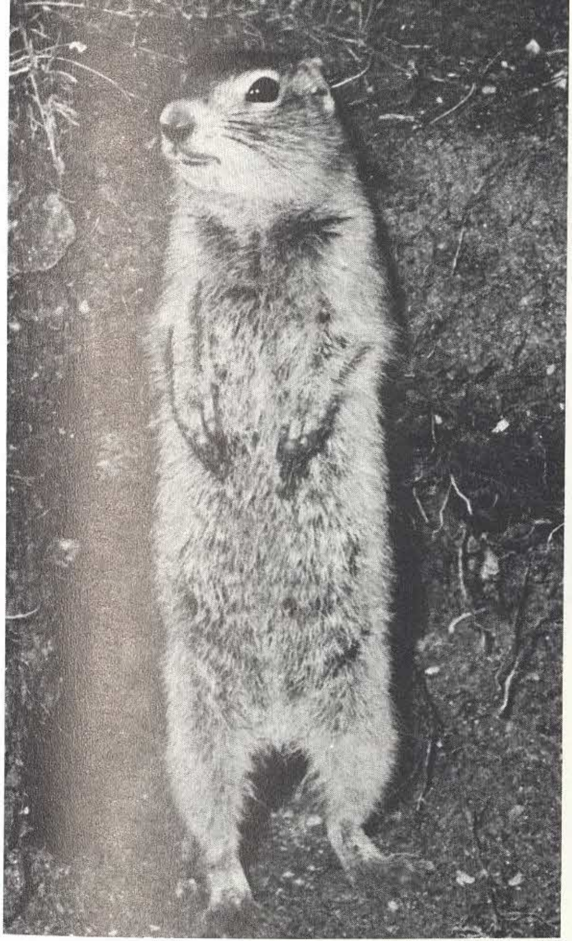
American Museum of Natural History

RODENTS

The rodents, or gnawing mammals, are the most abundant of all mammals in number of species and number of individuals. The land areas of the globe teem with these comparatively small-sized creatures. For the most part they are ground dwellers. Many live in colonies, constructing a vast system of underground chambers and galleries. There are, however, tree-living rats and mice, squirrels, and porcupines. Beavers and water rats are partially aquatic. All the rodents are herbivorous, or vegetation-eating animals, though some rats sometimes eat flesh.

One of the most curious things about the rodents is the regular fluctuation in the number of individuals of various species. For a period of several years there will be a noticeable scarcity of rats, mice, and other rodents. Then, during a single season, the populations of these animals will increase tremendously. This cycle of decrease and increase is due to various factors: the abundance or scarcity of predators; the reproduction rate of the plants upon which the rodents feed; the competition with other vegetation-eating species; disease; the amount of solar radiation reaching the earth. Obviously, when the number of rodents increases, there is increased destruction of natural and cultivated vegetation.

The rodents have had a long evolutionary history. Judging by fossil evidence, they were already flourishing something like 50,000,000 years ago. Apparently they descended from an insectivorous, or insect-eating, mammal resembling the modern-day shrew. The rodents did not include any giant species among their numbers. The largest rodent known was a beaver that



Charles Ott, Audubon/PR

lived in North America about 1,000,000 years ago; it was nearly as large as a black bear. Today the largest member of the group is the South American capybara, which is the size of a small pig.

DISTINCTIVE INCISOR TEETH

Typical rodents have a pair of large, chisellike front teeth, or incisors, in the upper and lower jaws. The bases of these teeth curve far back in the jaw bones. The molars, or cheek teeth, are often high-crowned. Since the canine teeth and some premolars are absent, there is a large gap between the incisors and the molars. Consequently the incisors can operate freely and food can be easily transferred from the front of the mouth to the grinding teeth. The strong muscles that control the lower jaw are adapted for moving it backward, forward, and crosswise, thus making a thorough grinding action possible.

The incisor teeth of the gnawing animals are a distinguishing feature. These teeth are the animals' most precious possession, for without them no rodent could survive. The teeth are self-sharpening. This is accomplished by a very ingenious arrangement. The outer surface is made up of a very hard enamel. The inner surface is composed of a softer bone material which wears away at a much faster rate. The difference in rate of wear causes the tooth to be always sharp. The same principle is used in the ax and chisel.

The rodent incisor is in constant use, and we might expect that it would be worn away to a tiny stump in a relatively short time. The fact is, however, that the tooth is constantly growing from a permanently active pulp. In some species, this is also true of the molars.

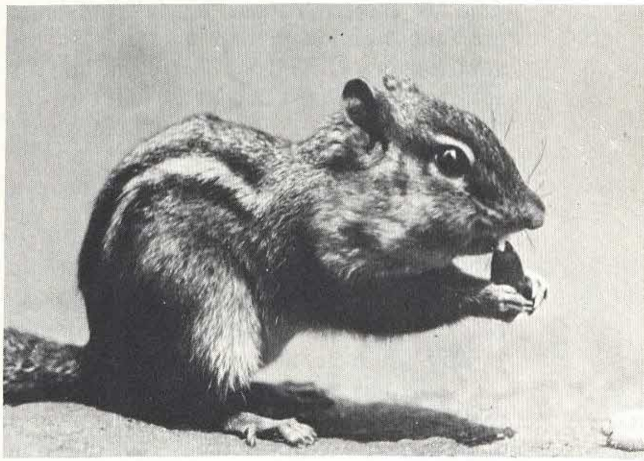
Another interesting adaptation in the rodent's mouth is the method of filtering out unwanted food such as foreign substances and chunks of food that are too large and would choke the rodent. As we have already mentioned, the typical rodent has a gap in its teeth between its incisors and its molars. The cheek fur extends inside the mouth and fills up this gap in the teeth. The hair serves as a screen or filter for the food.

MANY DIFFERENT KINDS

There are a great many rodents. Rats and mice make up the largest group in the order. The squirrels, including chipmunks,

The Eastern chipmunk is a ground squirrel. It is common in developed areas, as well as in the wild.

New York Zoological Society



prairie dogs, marmots, and other species, also make up a very large group. Among the other numerous rodents are hamsters, voles, lemmings, meadow mice, muskrats, gerbils, bandicoot rats, jerboas, dormice, jumping mice, agoutis, pacas, and capybaras. We can only discuss some of the more interesting rodents in this article.

SQUIRRELS

The squirrel family comprises one of the largest groups of rodents. In addition to the various species of tree squirrels, it also includes the ground squirrels, such as the woodchuck, marmot, chipmunk, and prairie dog.

Tree squirrels. Tree squirrels all have a long, bushy tail and a habit of hoarding quantities of seeds and nuts.

The European pine squirrel is the main species found in Europe and northern Asia. It is usually red in color and has long tufts on the tips of its erect ears. The male is about 20 centimeters long. The European pine squirrel changes its coat with the seasons. It has a grayish-brown coat in the cold months instead of a red one.

A close relative of the European species is the North American red squirrel. It is found particularly in the eastern half of the United States and Canada. The eastern gray squirrel is rather more familiar because it is seen frequently in yards and parks. It is like the red squirrel except for the color of its coat and its slightly larger size. The western gray squirrel is larger than its eastern cousin, has a handsomer tail, and has longer and finer fur. In the southeastern United States we find the fox squirrel, the largest in that area. It owes its name to its fox-colored coat and sharp, foxlike face.

Central America and Mexico have a large number of especially gay-colored varieties of squirrels. Two well-known species are the variegated squirrels and the Humboldt's squirrels. In South America, one finds the flame squirrels, the common pygmy squirrels, and the midget squirrels.

Asia has some of the most interesting of squirrel species. The common squirrel is most widely represented; 320 different ones have already been named. One also finds in Asia the largest squirrel of them all, the Oriental giant squirrel, which attains a length of nearly one meter.

Africa, too, has its share of squirrels. The oil palm squirrel is the largest, growing to over one third of a meter in length. At the other extreme, there is the West African pygmy squirrel, which has a head and body length of about eight centimeters.

Ground squirrels. There are several kinds of ground squirrels. *Marmots* are ground squirrels. They are too heavy-bodied and clumsy to climb trees. Instead, they make their homes in burrows in the ground. The American species of marmots are called *woodchucks* or *groundhogs*. These are hibernating mammals, reaching a maximum weight of six kilograms. The hoary marmot, so named for the color of its coat, is a native of the high mountains. Related to it is the European or Alpine marmot, found in Europe and eastern Asia. There are also Chinese and Kashmirian varieties of marmots.

The *prairie dog* is one of the most interesting ground squirrels. It was once one of the most abundant species inhabiting the great plains of North America. Before so many of them were poisoned by U. S. cattlemen, they could be found in giant underground prairie-dog towns which often extended for many kilometers.

Among *chipmunks* the eastern chipmunk of North America is easily recognized by the characteristic five stripes running down its back. This tiny rodent is often surprisingly tame. There is also a somewhat different western variety. It is more slender and has a longer tail and more stripes.

The pocket *gopher* is a well-known burrowing rodent. It constructs long tunnels during its lifetime. The name "gopher" is derived from the French word *gaufre*, meaning "honeycomb." The reference is to the maze of the animal's tunnels. The "pocket" part of the gopher's name refers to its cheek pouches, which extend from its cheek back to the shoulders and are used to carry quantities of food.

Flying squirrels. Certain rodents are

Beavers have very sharp incisors, which are used to gnaw through tree trunks. The beaver is the largest rodent in the Northern Hemisphere.

New York Zoological Society

gliding experts. The flying squirrels represent a familiar species of this type. They are able to glide because of a special adaptation – a loose membrane or fold of skin extending between the hind and front limbs. When the animal stretches out its limbs, the membrane is pulled tight, thus producing a wide gliding surface. The scaly-tailed squirrels of Africa are also able to glide.

BEAVERS

Some rodents take to the water. The best-known of these is the beaver, the largest rodent in the Northern Hemisphere. It attains a length of over one meter, including the tail, and it averages something like 15 kilograms in weight. With its webbed hind feet and its broad and flat tail, it is as much at home in the water as on land. Its thick, soft fur is much esteemed by furriers.

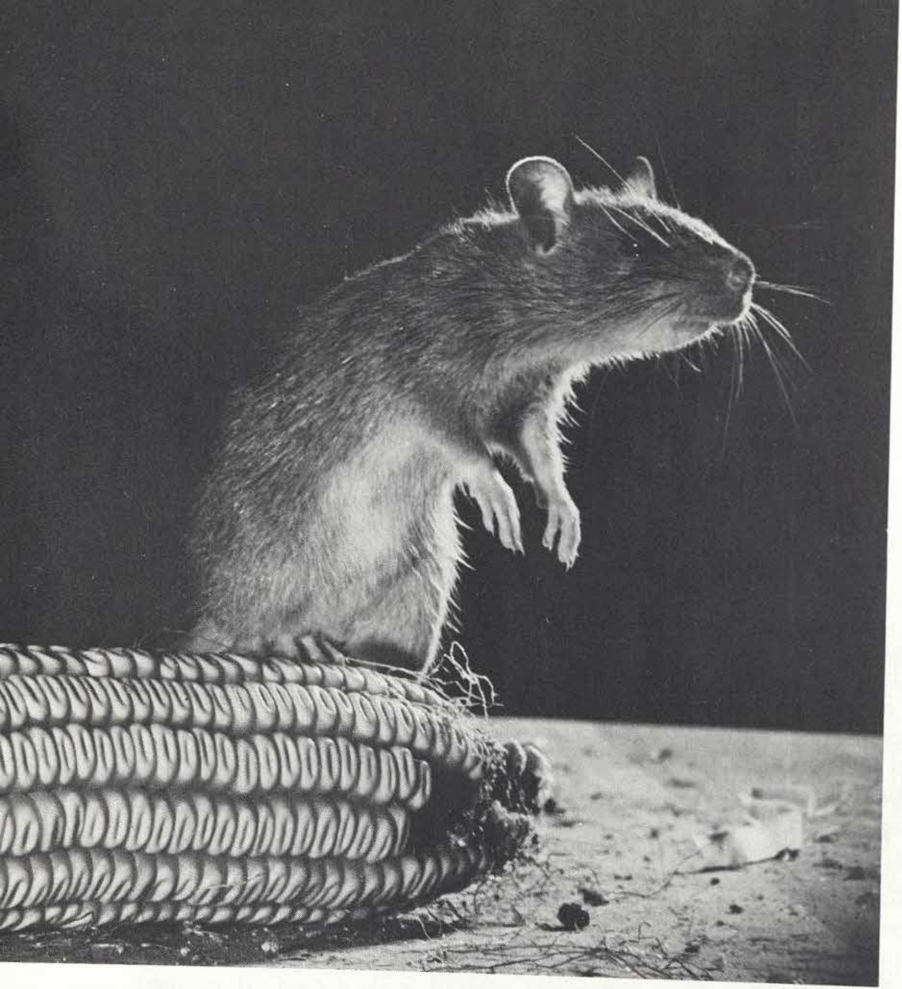
Beavers live in colonies in shallow streams. Each family consists of two parent beavers and their young up to the age of about two. Two-year olds leave their families in the spring in order to mate and to form their own families.

The beaver is an accomplished engineer and is particularly renowned for its dam-building. A beaver pair engaged in new dam construction will begin by felling trees near the proposed dam site. The two will work together at the task, gnawing through each tree close to the roots. Once the tree is down, the limbs are removed and the trunk is cut into lengths that the beaver can handle. The branches and logs are then hauled to the damsite. They are put into position in the water and held in place with rocks and mud. When the dam has been raised to the desired height, it is plastered with mud.

Next, the beaver constructs its *lodge* on the dam itself, or on a bank of a stream or on an island. The structure is of wood and twigs, heavily plastered with mud. When these materials freeze in the winter, they cause the lodge to become an almost impenetrable fortress. The chamber of the lodge has a stout arched roof. It is lined with twigs, vegetable fibers, and mud. There is a straight tunnel running down into the water. Through it the beaver brings up supplies that have been stored on the bed of the stream. Various other tunnels lead from the chamber into the water.

The nucleus of a beaver colony is the original pair of permanently mated adults. When the young grow up, they usually settle at the damsite, building another lodge and cooperating in the task of keeping the dam in repair.

In the colder months of the year, beavers feed on the supplies amassed on the stream bed. These consist of logs that have been cut to manageable lengths. The logs are taken into the chamber one at a time. The animals devour the bark and then throw out the rest. In the warmer months, the beavers feed on the roots and stems of plants growing in the water. They also go ashore and feast on the bark of trees.



The Norway rat is the most common rat in temperate regions. This rodent was imported to North America in the eighteenth century.

Philip Gendreau

PORCUPINES

One of the most curious rodents is the porcupine. This normally unaggressive creature rarely meets a violent death, because of its almost impenetrable defenses. The porcupines's quills are both a defense mechanism and a deadly offensive weapon. When threatened, the porcupine immediately raises them and turns its back to the foe. Some species will rattle their quills in warning just like a rattlesnake. If the warning is not heeded, the animal charges backward, forcing its quills into the threatening animal. Contrary to widespread belief, the porcupine cannot shoot its quills. Quills are not simply annoying. They can kill. There is a case on record of the finding of a dead panther whose head had been run through by seventeen quills. Two of them had penetrated the brain. Once a quill enters an animal's body, its end opens up into several small barbs which prevent the quill from being removed. It will actually work its way deeper into the victim. There are a number of species of porcupines on all the continents except Australia. The largest is the African crested porcupine, which measures nearly a meter in length.

RATS AND MICE

The Muridae, or mouselike family, constitutes the largest group in the rodent order. It is in this family that we find the multitudes of rats and mice.

The true rat alone has over 550 subspecies.

The rats are the most widespread members of the order of rodents. They are found almost everywhere that man himself dwells. The fight against them has been a continuous one and, so far, a losing one. In North America, despite all of man's efforts to destroy them, there are more rats than people. The rat found in most temperate regions is the Norway rat. It first came to North America, probably about 1775, by ship. The Norway rat ranges from 10 to 30 centimeters in length and its scaly tail is even longer. Its color varies from gray to grayish-brown and it breeds as often as twelve times a year.

In South America and southern Europe, a black, slightly smaller variety is more common. Both species are believed to have originated in China and spread west.

The rat has managed to thrive, despite man's utmost efforts to destroy it, because it is fertile, hardy, voracious, adaptable, cunning, and courageous.

In addition, there are the rice rats, cotton rats, roof rats, water rats, tree rats, and so on ad infinitum.

There are also innumerable kinds of mice. There are more than 130 subspecies of the common mouse. There are also field mice, pygmy mice, harvest mice, and white-footed mice, to name only a few.

HAMSTERS

Hamsters are natives of Europe and Asia. The animals that are now being bred in North America as pets were imported from there. The name comes from the High German word for "weevil." Like weevils, hamsters are burrowers. They venture from their underground homes only at night. They subsist mainly on grain and tubers. The European hamster is somewhat larger than the golden hamster that is so well-known in the Western Hemisphere.

GERBILS

The gerbils live in the hot, arid desert regions of Asia, Africa, and the southern Soviet Union, often many kilometers from water. Communities of these animals make their homes in underground tunnels and burrows. Ratlike in many ways, they differ from most rats in having rather large ears and in leaping instead of scurrying along. The gerbils resemble the jerboas closely. It has, in fact, been suggested that "gerbil" is just another form of the name "jerboa."

Jerboas are nocturnal in habit. They are buff-colored little rodents with rabbitlike ears and kangaroolike locomotion. They have been credited with attaining speeds of up to 65 kilometers per hour.

DORMICE

The dormouse is an Old World species. The name, coming from the French *dormir* ("to sleep"), is very appropriate. The dormouse is one of the hibernating mammals, sometimes sleeping for six months at a time. During the months that it is active, it sleeps throughout the day and ventures forth at night. Thus, the animal may spend as much as three-quarters of its six-year life in slumber. The dormouse closely resembles the squirrel. It has a long, bushy tail, soft, silky fur, and large, round eyes. It also resembles the squirrel in its habit of spending a good deal of time in the trees. Like the squirrel, it feeds on nuts, acorns, and seeds.

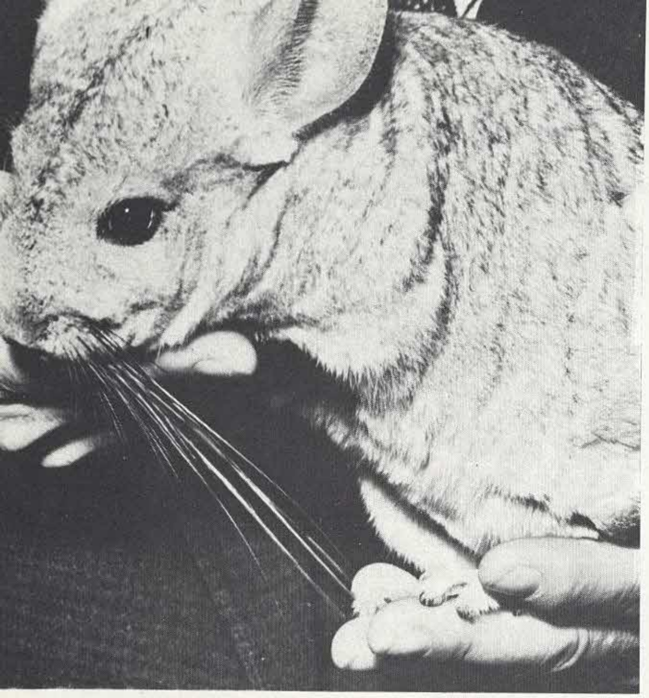
MUSKRATS

The muskrat is trapped in North America for its fur. It is the most valuable fur-bearing animal in North America if one considers the total number of skins that have been sold. However, the animal is so prolific that there is no danger of the species being wiped out. It gets its name from a secretion of its hind quarters. This secretion gives off the odor of musk and is used in the manufacture of perfume. The muskrat is usually found in the marshy regions of North America.

LEMMINGS

One of the most curious patterns of behavior to be seen in the rodent family is the famous death march of the Scandinavian lemmings. The lemming is a small, heavy-bodied rodent, usually about 15 centimeters in length and covered with soft, golden fur. The Scandinavian variety has patches of glossy, black fur behind the shoulders.

A colony of lemmings is formed on a mountain slope, where it soon grows to considerable proportions, depending upon the severity of the weather and length of the warm season. If spring comes early and there is a long warm season, the colony



Ewing Galloway

The chinchilla is native to South America. It is now raised in North America for the fur industry.

grows rapidly. Because of the longer season, there is more vegetation to feed the increased number in the colony, but a long summer also tends to scorch the vegetation because of the excess heat. This reduces the normal supply of food – a serious condition because of the greater number of lemmings. Suddenly, as if a signal had just been given, the rodents start migrating toward the sea. The instinct seems to affect all the lemmings in the colony. It is unknown whether or not some of them remain behind to start up the colony again, but if they do, they have not been observed, although the lemmings appear again after a few years.

Like a huge army, the host of lemmings begins its march. Many will perish before they even catch sight of their destination. As they move along, all the food encountered by the long column is eaten by those in the front ranks, while the rest go hungry. Ordinarily, they do not swim, but now they cross rivers and fjords without hesitation. Huge numbers of lemmings are eaten by birds of prey, foxes, and even ordinarily herbivorous animals, such as the caribou. When the lemmings reach the sea, they plunge in and drown en masse. Little is now known as to why lemmings behave this way. Some authorities interpret the phenomenon as a kind of population control, because it occurs when the weather is mild and the lemmings are reproducing very rapidly. There are distinct changes in the blood, for example, of Alaskan lemmings, such as increased concentrations of hormones and other biochemicals, during these reproductive periods. It is possible that one of these blood chemicals attacks the nervous system, causing violent behavior.

COYPUS

Another puzzle, of a similar sort, arose in connection with the coypu *(Myocastor coypus)*, or nutria, as it is called. A large, muskratlike aquatic rodent, characterized by partially webbed hind feet, it inhabited the river banks of South America. In the late 1840s, hunting coypus for their pelts was so popular that peasants were not willing to work on the sheep and cattle ranches during the summer months. In order to protect the ranchers from ruin, coypu hunting was made illegal. As a consequence, the coypu swarmed everywhere. It even changed its dietary habits and its habitat, establishing itself on dry land many kilometers from the nearest river. Then, quite suddenly, for no known reason, the coypu became practically extinct. In recent years, it has been introduced to the United States, where it now appears to be thriving.

CHINCHILLAS

Among the few valued representatives of the fur-bearing rodents are the South American chinchillas, small burrowing animals with bushy tails. Chinchilla fur, which is much prized for its beauty, is silky in texture and a delicate pearl grey in color, darkly mottled on the upper surface and dusky white beneath. In mountainous districts of Peru and Bolivia, the chinchilla is well-known, and here the little creature attains its greatest size, 25 centimeters or more with an imposing 25 centimeter tail. The chinchilla is also found along the coastal area of Chile, while one variety, the visacha, is native to the Argentine pampas. Chinchillas live in large colonies, remaining in their capacious burrows by day and venturing out at twilight to forage and work on their tunnel-building enterprises. As in the Peru of the Incas, the chinchilla is still hunted for fur.

AGOUTIS AND PACAS

Other species of South American rodents are the agouti and its close relative the paca. Both resemble over-sized guinea pigs, the agouti measuring from 45 to 50 centimeters in length, while the paca is more than one-half meter long. These rodents are long-legged, with broad flat nails on their toes. Their ears are small and their tails insignificant. They are not gregarious like the colony-loving chinchillas but dwell in pairs or little groups. One variety of paca lives in the lowlands of Mexico and the eastern part of South America. Another inhabits the lofty forests of the Andean foothills in the countries of Ecuador and Venezuela.

CAVIES

A third group of southern rodents is the cavies, small plump creatures with short legs. Perhaps the best-known cavy is the domesticated *guinea pig*. It is probable that this pet and research animal derives from the Peruvian cavy of the Incas. The cavy lives chiefly in marshy districts where it can burrow in the soft earth. However, the rock cavy of Bolivia dwells in colonies amid the high and rock-strewn slopes of the great mountain range of the Andes, in South America. The rock cavy is highly prized by the Indians as a delicacy.

Another member of the cavy family is the Patagonian cavy. At first glimpse, this elongated rodent might be mistaken for a large hare. The Patogonian cavy is 45 centimeters in length and has a five-centimeter tail. It stands over 30 centimeters in height at the shoulder. The creature is colored a light cinnamon on the flanks and breast, while the belly is white. This cavy, with a smaller relative, the dwarf Patogonian cavy, inhabits the salt wastes of the Argentine.

CAPYBARAS

The largest of the rodents is the capybara, found in the South American forest regions from Guiana to the River Plate. The size of a year-old pig, the capybara attains a length of more than one meter and stands 50 centimeters at the shoulder. The capybara is a strong swimmer and forages in herds of from fifty to one hundred. Herbivorous, constantly on the move, denuding whole districts of fruit and vegetation, this rodent can be a considerable nuisance in agricultural regions.

Top: a female Patagonian cavy nurses her young as her mate stands guard. Bottom: capybaras, native to South America, can grow as large as pigs.

A. W. Ambler, Audubon/PR

A. W. Ambler, Audubon/PR

SEALS AND WALRUSES

A person who is not familiar with sea lions may wonder just what kind of animals they are. They have coats of hair like mammals, but their flippers seem to have nothing in common with the feet of mammals. Are these flippers like the fins of fish, or are they like the paddles of the whales and dolphins? The truth is that sea lions are flesh-eating mammals that long ago returned to the sea to live an aquatic life. The limbs of the sea lions and their kin—the walruses and seals—have bones that correspond to those found in the limbs of the land mammals. Moreover, the teeth and skulls of these aquatic creatures show they are related to carnivorous land mammals.

The seals and walruses are large, bulky mammals with rudimentary tails. Their external ears are very small or absent altogether. The body hair of the different groups varies from the finest of fur to coarse bristles. These creatures prey upon fish, squid and other mollusks, crustaceans, and, occasionally, sea birds.

We can trace these mammals back as far as the Miocene period, some 25 million years ago. Some zoologists think that they are descended from the earliest and most primitive carnivores called the *creodonts*. Others believe that they evolved from a later carnivore stock that produced the dogs, bears, weasels, and otters. The fossil remains of a mammal with seallike characteristics were found in a Siberian geological deposit that was about 10 million years old. This mammal had a long, slim tail and limbs that indicate it could walk on land as well as swim. It also had features similar to those of the otter. This ancient carnivore itself could not have been a direct ancestor, but the animal may have been derived from the ancestral group that gave rise to the modern seals and walruses.

A Weddell seal prepares to dive for prey. Weddell seals are true seals that live in Antarctica.

Herbert G. Ponting

MODIFIED LIMBS

The limbs of seals and walruses have undergone a strange transformation. The upper and lower leg bones have been much shortened, while the front and hind feet have been lengthened. There has been no increase in the number of toes. A web of skin grows between the toes, thus forming the flipper, or fin. These mammals, unlike all other aquatic vertebrates, swim entirely by means of their limbs. The two hind legs are directed backward to serve, in swimming, as a substitute for a tail. The front legs are well suited for steering. The eared seals, which include the sea lions and fur seals, can bring their hind legs around in a forward position when they are traveling on the land. This is also true of the walruses. The earless seals, of which the elephant seal is an example, cannot turn their hind limbs forward at all. When on the beaches, these animals are barely able to drag themselves along.

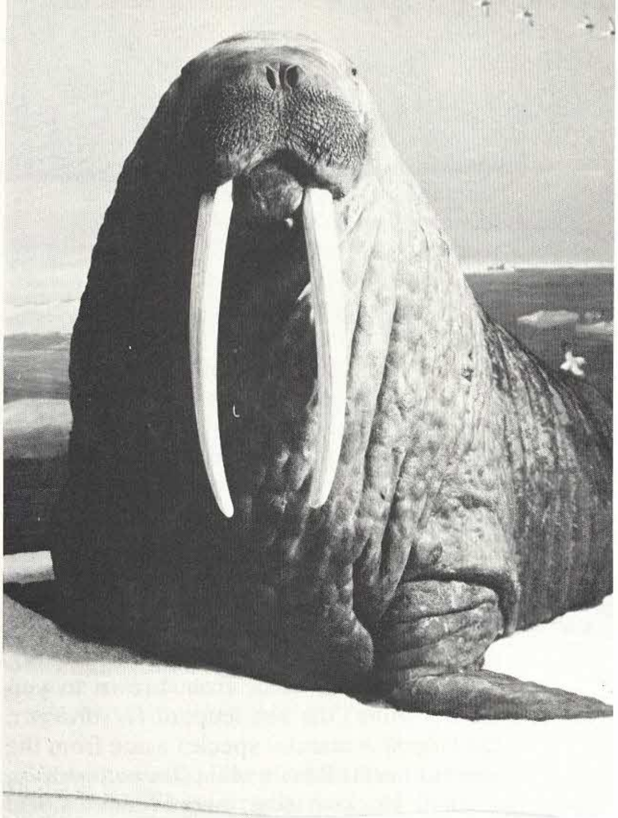
Why should seals and walruses retain leglike limbs for land travel when in other respects they are so remarkably adapted for life in the sea? The reason is that all of these aquatic mammals must leave the water to breed and raise their young, and consequently need supports on land for their large bodies. When the ancestors of these mammals first took to the water, they were probably as agile on the land as most other carnivores. But in time they became adapted to an aquatic environment and came to the land less frequently.

SPECIALIZED FOR SWIMMING

Seals, sea lions, and even walruses are graceful and powerful swimmers. Sea lions, when they are swimming slowly, use their front flippers as paddles. When they go faster, they also work the hind limbs. The elephant seal moves only its rear flippers to swim. Weddell's seal presses together the bottom surfaces of its hind feet and waves this apparatus from side to side. The animals often dive to considerable depths and remain submerged for some time. The maximum time spent under water has been recorded for several species. For instance, the elephant seal can stay submerged twelve minutes; the harbor seal, fifteen; and the harp seal, twenty minutes. How is this possible? First, these mammals, unlike land species, almost completely renew the air in their lungs when they breathe. The respiratory center of their nervous system does not respond quickly to an increase of carbon dioxide in the blood, and so does not demand more rapid breathing. Finally, when under water, the animals distribute breathed-in oxygen only to those parts of the body involved in essential activity. Seals show an additional adaptation: during a dive their heartbeat slows from 80 beats per minute to about 10 beats per minute. This allows the seal to conserve oxygen.

TWO FAMILIES

The seals, sea lions, and walruses (sometimes known collectively as pinnipeds) are classified in two families. Included in the family Otariidae are the fur seals, sea lions, and walruses. These animals have long necks, small external ears (except the walrus), and front limbs nearly equal to the hind limbs in length. The northern fur seals (genus *Callorhinus*) of the North Pacific and the southern fur seals (*Arctocephalus*) of the Southern Hemisphere possess a luxuriously soft and dense underfur. The sea lions, which lack this underfur, include the California sea lion (*Zalophus*), the northern sea lion (*Eumetopias*), and the southern sea lion (*Otaria*). The California sea lion has a high forehead and glistens black when wet. It gives honking barks. It lives along the coast of southern California and through the central Pacific to New Zealand, Australia, and Japan. The northern sea lion, which is larger and has a low forehead, ranges chiefly in the North Pacific, though it will go as far south as southern California. The walrus (*Odobenus*) of the Arctic is distinguished from the fur seals and sea lions by its great size and large tusks, which are elongated, upper canine teeth.



American Museum of Natural History

The walrus is a stoutly built animal that lives in Arctic regions. The male's tusks may grow to one meter.

The earless, or hair, seals of the family Phocidae lack external ears, have a very short neck, and possess forelimbs much shorter than the hind ones. Common seals (*Phoca*) of the northern seas include the small and spotted harbor seal; the ribbon seal, which has yellow bands around its neck, rump, and front flippers; the ringed seal, with whitish rings on its sides; and the harp, or Greenland, seal, which has along its sides dark bands that join across the shoulders and over the rump. The large bearded seal *(Erignathus)* of the Arctic is distinguished by bristles on the sides of its muzzle. Another large seal of Arctic waters is the gray seal, *(Halichoerus),* a uniformly grayish animal.

The male hooded seal *(Cystophora)* of the North Atlantic differs from other seals by having a pouch atop its forehead and snout. This bag is inflated when the animal becomes annoyed. The closely related sea elephants, or elephant seals *(Mirounga),* are giant species living in the Antarctic, South Pacific, and Indian Oceans and off the coast of Baja California.

Other seals of the Antarctic and South Pacific are the crab-eating seal *(Lobodon),* which varies in color from brown to yellowish white; the sea leopard *(Hydrurga),* the largest Antarctic species aside from the elephant seal; Ross's seal *(Ommatophoca),* a small blackish seal; and Weddell's seal *(Leptonychotes)* of the south polar seas, blackish, peppered with silver and gray. The monk seal, *(Monachus)* is a large animal, black above and whitish below, inhabiting the waters of the Mediterranean, Caribbean, and central Pacific.

SOCIAL BEHAVIOR

Almost all pinnipeds are gregarious, or social, animals, though the sea leopard, Ross's seal, and the bearded seals seem to lead solitary lives.

Sea lions and fur seals make long migrations to their breeding territories, where the males gather a large number of females together into *harems,* or groups.

Of the earless seals, only the male gray seals and elephant seals gather harems of females in the mating season. Some earless seals migrate to their breeding ground, but other species rear their young upon shores or ice floes wherever they happen to be.

The breeding fur seal bulls, or males, arrive at the breeding grounds about the end of May or the beginning of June and take up positions along the shore, awaiting the coming of the cows, or breeding females, a few weeks later. The cows are pregnant when they arrive. Each male now obtains as many cows for his own harem as possible. He emits loud roars designed to frighten away his competitors. Violent fights occur between breeding males. The bulls inflict serious wounds with their sharp, powerful teeth. As the bulls seek new cows, the ones they have already secured may be stolen by other bulls farther away from the water's edge.

The stronger the bull, the more mates he obtains. The harems of the large bulls average about thirty cows. However, some bulls may manage to gather as many as a hundred cows. The competition is so strong and so continuous that the bulls will not leave the beach to feed at sea. As a result, they may go for several months of the year, fighting and mating, without eating at all.

Shortly after the cow arrives at the breeding ground, she gives birth to the single pup conceived the previous season. About a week later she mates for the next year. Four to six weeks after birth, the seal pup learns to swim. During the summer, the cow frequently swims out to sea to feed, returning at gradually lengthening intervals to nurse her pup. The senses of the seal are apparently so acute that she has no trouble in finding her own offspring among the many thousands she encounters when she returns to the swarming beach. About four months after it is born, the young seal is weaned.

With the approach of winter, the seals move out to sea until the following summer. By this time, the seal pups are far enough along in their development so that they are able to accompany their mothers on the long swim to warmer latitudes. On their migration to and from the summer nesting grounds, seals are subject to attacks by many sea predators, particularly the killer whale, which may swallow as many as twenty or more seals at a single feeding. It is estimated that not more than half of the seal pups ever reach maturity.

FUR SEAL INDUSTRY

Because of its habits, the seal is an easy prey. In the eighteenth century, Russian seal hunters wrought havoc among the fur seal rookeries on the Pribilof Islands off the Alaskan coast. The seals were killed and skinned. The animals were hunted so avidly that one species, *Hydrodomalis stelleri*, became extinct within twenty years of its discovery. Several other species became too rare to be hunted profitably. In time the Russian government realized the seriousness of the situation and put a stop to this destruction. Then, in 1867, the islands were purchased from the czars by the United States. The sealing rights were then leased to private companies and the slaughter was resumed. *Pelagic sealing,* or catching seals at sea, became common. Since the herds migrated in huge groups at fairly regular times, they were easily located. Unfortunately, when a cow was killed, the herd lost not only that female but the pup it was carrying. If the female was killed in the late summer or early fall, it also meant the death of the pup she was nursing.

But the fur seal of the North Pacific, happily, has been saved from extinction, at least for the present. In 1911, the nations most interested in the sealing industry and therefore concerned with the rapid depletion of the herds finally agreed upon measures safeguarding the fur seals.

The two most important fur-seal rookeries are those located at the Pribilof Islands, Alaska, and the Komandorskiye Islands, in the Bering Sea. The Pribilofs belong to the United States and the Komandorskiye Islands to the Soviet Union.

A new Alaska fur seal law, agreed upon by Canada and the United States, still prohibits the killing of seals at sea. Sealing operations on the Pribilofs are carried on by natives of the islands who are under direct government supervision. New laws enacted by the U.S. Congress may affect the agreements presently binding on the United States. If danger of extinction exists for these animals, treaty agreements may be modified.

Since one hardy bull seal may maintain up to one hundred cows in a harem, and since an equal number of male and female seals are born, there is an excess of bulls in every rookery. These surplus bulls, which are called *bachelors,* are either too young or too weak to fight for a harem. They accordingly separate themselves from the rest of the herd. These are the majority of seals that are killed for their pelts. A certain number of bachelors are allowed to escape, however, so that they may become harem masters in the future.

Australian News and Information Bureau

An adult fur seal found in the waters of the Southern Hemisphere, sometimes as far north as Australia.

WALRUSES

The walrus is another pinniped that may visit the Pribilofs, though it usually keeps to the Arctic seas. It is a good swimmer but cannot endure a long-distance trek such as is made by the fur seal. Often it will climb aboard ice floes and let the ocean currents carry it along. Walruses begin their northward migrations in May, and during the journey young are born and mating occurs. When the Arctic waters freeze over, walruses may go as far south as Labrador in the Atlantic and to the Bering Sea in the Pacific.

The walrus is a ponderous seal-like mammal, weighing as much as 1,300 kilograms. It has a massive neck, which supports a proportionally small head. Its muzzle is broad and blunt and is studded with coarse, stiff bristles. Short, reddish hairs scantily cover its thick and wrinkled hide. Like the eared seals, the walrus turns its hind feet under its body to assist it when walking on land or ice.

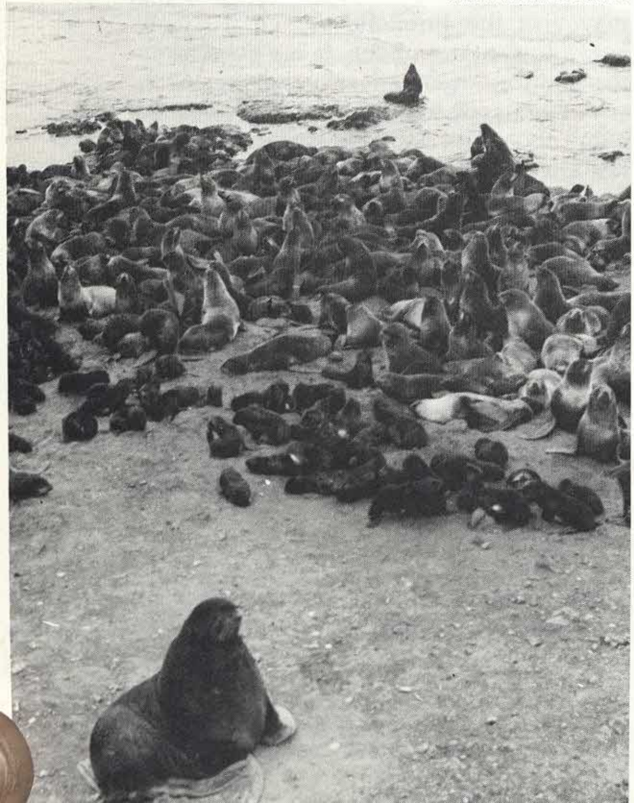
The characteristic mark of adult walruses is the possession of a very fine pair of ivory tusks, which are really elongated canine teeth of the upper jaw. The tusks of the male are quite straight and may grow to a length of one meter. Those of the female are shorter, more slender, and somewhat curved. The tusks make formidable weapons in defense and in fighting for a mate. They are also efficient tools for digging in the sediment of the ocean floor for mollusks, such as clams, snails, and oysters. Besides mollusks, walruses eat starfish and shrimp.

Walruses keep together in small herds, spending their time on shores or on ice floes. Though usually mild in manner, they become aggressive during the mating season, or when attacked, or when their young are threatened. Man is their greatest enemy, but they also fall victims to polar bears and killer whales.

The prosperity of some Eskimo tribes depends to a great extent upon the herds of walruses. These Eskimos use every bit of a walrus carcass. The flesh is eaten, the hide is made into leather, the intestines serve as a substitute for window glass, the tusks are carved, and the oil is burned to provide light.

A fur seal rookery on the Pribilof Islands. Large males may keep as many as 100 females in a harem. Bachelors wait offshore.

U.S. Fish and Wildlife Service



TRUE SEALS

True seals do not move well on land or ice. Not only are the hind limbs of little use, but their fore limbs are quite small and their necks are so short that they can barely lift their heads. Their pelts have long, coarse hair and lack the characteristic underfur of the fur seals. The habits of the harp and hooded seals are somewhat similar. These animals often migrate together. Early in February they head northward for the Strait of Belle Isle or the Gulf of St. Lawrence, where the young are born, or whelped, sometime in March. Until the young harps are able to swim, they are left on sheets of thin, drifting ice. The old seals leave and approach their babies through holes made in this ice. The hooded seal young are whelped on ridges of ice, which are approached directly from the sea. Hooded seals scatter in small groups away from the herds of harp seals. Of the true seals, the harp and hooded seals are the ones chiefly hunted by the commercial sealers for their hides and blubber.

Other true seals are found along rocky coasts or about islands and ice floes of most seas. Certain species even live in inland waters. The Caspian seal dwells in the Caspian Sea. The Baikal seal flourishes in Lake Baikal, which is a large freshwater lake of Eurasia. Since these seals are awkward on land, their presence here suggests that these waters had a former connection with the open sea.

But seals can travel on land, if necessary—a short way in a long time. It is recorded that a gray seal traversed nearly fifty kilometers of snow-covered land in Norway, the time taken, it is believed, being about a week. Whether they would have endurance enough to find their way from some other watercourse to the inland seas mentioned is, of course, another matter.

Many seals are destroyed on land by polar bears, and many in the waters by killer whales. The shark is also an enemy of this animal.

The common seal along U.S. coasts is called the harbor, or leopard, seal. It is one of the smallest of the true seals, rarely exceeding a length of two meters, and is whitish in color, heavily spotted with gray. It sometimes finds its way into the Great Lakes or other inland bodies of water having a connection with the sea. It is found in both the Atlantic and Pacific as far south as North Carolina and Baja California though not abundant south of Maine and British Columbia. It is not as gregarious as other seals and, therefore, in no present danger of extinction.

ELEPHANT SEALS

Because of lack of space we cannot mention here all the various genera of the true seals, but the sea elephant, or elephant seal, must be noted. This is indeed a prodigious beast, with a length of about six meters, and a girth of about three meters. These dimensions relate to males only, for the females are considerably smaller. The enormous coating of blubber in which the animal is enveloped is a perfect protection against cold, for it has been found that the body of a sea elephant that has lain for twelve hours in the icy water of the Arctic fully retains its internal heat. Formerly found in enormous herds, sea elephants are now relatively few in number.

One species, the California sea elephant, nearly became extinct in the early years of the twentieth century. Conservation practices in those days were decidedly sketchy, to say the least. The animals had been considered fair prey for years by whalers and sealers, and there was an indiscriminate slaughter of them. The few that remained made their final bid for life on the island of Guadelupe, off the coast of Baja California. Since there was no law to protect them, it seemed only a matter of time before they would all be slaughtered by hunters of whales and seals. But this was not the only threat to their existence. A rich English collector sent out an expedition to Guadelupe in order to obtain a number of preserved specimens for museums.

The sea elephants on Guadelupe, manaced by commercial killers and scientific killers, seemed doomed to destruction. Fortunately, however, some of the animals either managed to escape detection or else were not on the island when the slaughter took place. When Guadelupe was visited by an exploring party in 1919, a small herd of the enormous beasts was still holding its own.

These seals breed from February to June. During this period they are often to be found on the shore. Here they are sluggish and clumsy. They appear to be quite unaware that they have a deadly potential enemy in man. They show no signs of fear when humans approach them. When they are attacked, their attempts to escape are pathetically futile, since they move about with difficulty on land and quickly become exhausted. They are more truly in their element when swimming about in the sea. In the sea, their chief enemy is the killer whale.

Another species of sea elephant makes its home in the vicinity of various islands in the Antarctic region. The big animals live on friendly terms with their neighbors, the penguins. They have a better chance to survive than their nothern cousins.

A bull elephant seal. Only males have the large trunklike snouts that give the animals their common name.

Alexander Lowry/PR

WHALES

The great whales are among the most fascinating creatures that have ever lived on earth, and one of them, the blue whale, is the largest. People in ancient times thought of whales as fearsome monsters of the ocean depths. So to hunt a whale, when one occasionally swam toward shore, was high adventure. People found the adventure was rewarding, too, for the oil and meat from one whale alone could heat and feed a village for a whole winter.

Ever since those early times, humans have felt for whales a sense of wonder mixed with an intense desire to capture, slaughter, and exploit them. Now the slaughter has reached alarming proportions. Even though some species are protected by the regulations of the International Whaling Commission and theoretically all whale hunting is regulated, the earth's stock of whales is still being depleted. In fact, some scientists worry that 200 years from now there may be no whales left. If this happens, mankind will be to blame for removing from the earth forever a remarkable and awe-inspiring creature that has always fed man's imagination and made the world a more exciting place.

Whales resemble huge fish. They were referred to by the ancients as "great fish," and any whale beached along the coasts of England was designated "the King's fish" because it automatically belonged to the Crown. But whales are not fish. They are warm-blooded, air-breathing mammals and are descended from a thinly haired, four-footed creature that lived on dry land.

About 70,000,000 years ago the whales' ancestors took to the sea by stages and gradually developed a streamlined shape and other characteristics that enabled them to survive in their new environment. They became marine mammals, who, though they live entirely in the water, function and behave in many ways that are usually associated with land animals. For example, whales bear live offspring, nurse their young, and breathe through lungs. Because they are lung breathers, they must surface at regular intervals to take in air, and, just like land mammals, they can drown.

Whales belong to the order Cetacea, which they share with the dolphins. The word "Cetacea" comes from the Greek work *ketos*, meaning "whale," and all members of the order are technically whales. But this article will deal only with those large members of the order that are commonly called whales. The dolphins are covered in a separate article. In the present article we shall describe the nine species of very large whales known as the "great whales" and a number of other kinds of whales that, though not big enough to be called "great," are nevertheless important.

A MAMMAL ADAPTS TO THE SEA

As those mammals that were someday to become whales gradually moved from the land to sea—either to escape predators or to find a new food supply—they probably went through stages when they lived partly on the land and partly in the water. At last they broke their ties with the land altogether and lived entirely in the sea. In the course of this land-to-sea movement, which occurred over millions of years, the whale underwent bodily changes that made it adapted to sea life.

The whale developed a streamlined, muscular body well suited to nearly constant swimming. The front legs became flippers, and the hind legs disappeared. Heavy horizontal tail fins, or flukes, developed from the tail.

All hair vanished except for a few bristles on the head, and the nostrils moved to the top of the skull, where they are now the *blowholes*. The external ears vanished but the inner ear remained, and whales seem to have more sensitive hearing than any other mammal but the bat. In the water the acute hearing takes over most eye functions and permits the whale to sense the presence of obstacles and find food. A whale's hearing

Great numbers of white whales in their breeding grounds in Canada's Northwest Territories. This rarely seen view, taken with special water-penetrating film, shows the adult and young whales as well as the physical characteristics of the breeding grounds.

Eastman Kodak Co., photo by J. Douglas Heyland, Quebec Wildlife Service

also enables it to communicate with fellow members of its group, often known as a herd.

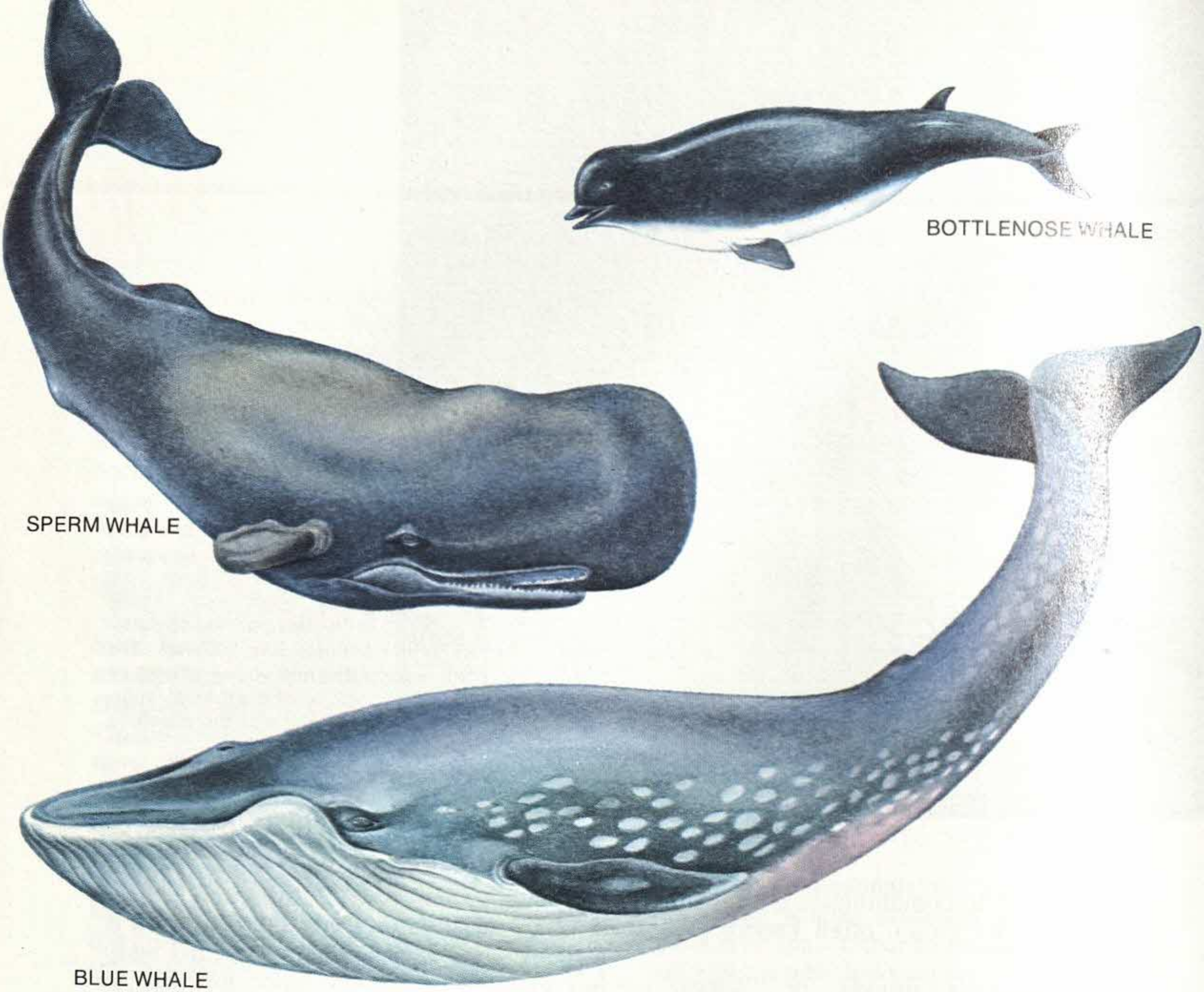
Whales emit sounds, or "songs," which vary according to the species. The whale's sound waves strike distant objects and bounce back to the whale, setting up vibrations in the middle ear. The timing and direction of these vibrations, or echoes, let the whale know where obstacles are located and also tell it where to find its food. Some scientists, discovering the ears of certain beached whales to be full of parasites, think that whales may run aground because impaired hearing makes them lose their ability to "echolocate" the shoreline.

TO LIVE IN COOL WATERS

Animals produce heat as a result of their normal bodily functions. Some animals—birds and mammals, including whales—are able to maintain a fairly constant level of heat, or temperature, in their bodies in spite of wide variations in the temperature of their surroundings. These are known as warm-blooded animals, or *homeotherms*. A healthy person (a mammal), for example, will have a body temperature of about 37° Celsius whether it is a warm day or a cold day. Special body features and activities work together to maintain this constant body temperature.

In the whale special body changes, or adaptations, permit it to live in the cold environment of the ocean. One of these adaptations involves size. The larger a mammal is, the relatively smaller its surface area is in proportion to its mass. Heat production takes place throughout the mass of an animal, heat loss through its surface. A 30-meter long whale has a large skin surface where heat loss occurs, but an even greater bulk—100 metric tons or more—where heat production takes place. Thus the whale's large size functions as one of its adaptations to its often cold environment. Of far more adaptive importance, however, is the whale's blubber.

Blubber is a thick layer of fatty fibrous tissue that lies under the paper-thin hairless skin of the whale. A poor conductor of heat, blubber provides whales with good insulation from the cold. In spite of these adaptations, most whales when at rest lose



heat more rapidly than they produce it through their normal body functions. They therefore swim to keep warm.

Blubber probably also serves as a food reservoir. This idea is supported by the fact that some whales have a much reduced blubber layer in winter when they eat very little. Blubber also reduces the specific gravity of the whale, thus making it more buoyant, and probably forms an elastic covering that allows for changes in volume during deep dives.

CARING FOR THE YOUNG

The whale calf is not as well protected from the cold as the adult whale, since it is smaller and has less blubber. However, it is born in relatively warm waters. Though most of the great whales feed in the cool seas near the poles, they migrate to warmer seas to mate and give birth.

During the mating season, the male and female of some species swim side by side, rub and nuzzle one another, give each other resounding blows with their flippers, and jump clear of the water, falling back with a great splash. Normally only one young is produced after a gestation period that varies from about 1 year in some kinds of whale to about 16 months in others. At the end of the gestation period, delivery of the young from the female's uterus is rapid. The infant swims from birth.

Within the first 24 hours, the newborn whale begins to nurse from its mother's mammary glands, which are situated in a pocket on the rear belly and are enclosed in a compressor muscle. Nursing by the infant is very brief. The mother, swimming slowly, turns on her side. As the infant touches the nipple of the mammary gland, a contraction of the muscle surrounding this gland squirts milk into the infant's mouth. The milk is very rich in minerals, proteins, and fats. On this diet the young grow rapidly. Young whales nurse for 2 to 7 months after birth. Sexual maturity is reached by most whales in their third to fifth year. Their life span is thought to be about 20 years.

THEIR DEEP DIVES

Whales can spend long periods of time under water—as much as 2 hours in some species—and can dive deeply; this deep diving is known as *sounding*. They are able to sound because of special adaptations of their respiratory and circulatory systems. The nostrils, or blowholes, are on the top of the head, and the nasal, or air, passages go directly to the lungs without joining the throat.

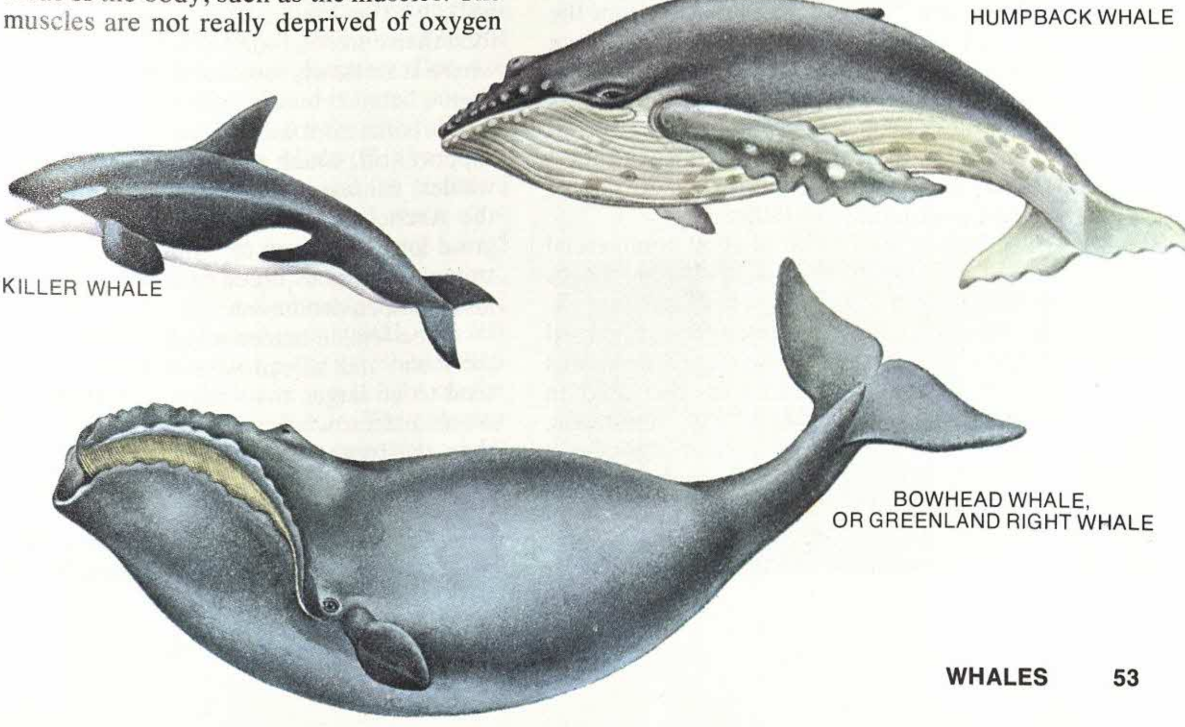
When the whale surfaces, it "blows," or breathes out, through these passages, usually making a visible plume of condensed air, its most characteristic feature. When it breathes in again, the small but very elastic lungs are quickly filled with large volumes of air. After the intake of air, special networks of blood vessels throughout the body store up an extra supply of oxygen. When another dive is made, valves close the nostrils. The heartbeat slows down and oxygen is conserved by the shunting away of blood from non-vital areas of the body, such as the muscles. The muscles are not really deprived of oxygen at this point, however, because oxygen has already been stored there. All in all, the whale's metabolism tends to store and save oxygen, which enables the whale to wait a fairly long time between breaths of fresh air.

THE ORDER CETACEA

The order Cetacea is divided into two suborders, the Mysticeti, or baleen whales, and the Odontoceti, or toothed whales. The chief difference between the two suborders is in their equipment for feeding, although there are other important differences, too. The baleen whales lack teeth, and instead have plates of *baleen,* a horny, fringed substance, hanging down from the upper jaws. With this they strain their food out of the seawater. The toothed whales, on the other hand, have teeth—with which they grasp their prey before swallowing it whole.

Of the nine great whales, eight are baleen whales. These eight species are the blue whale, the fin whale, the sei whale, Bryde's whale, the humpback whale, two species of right whales, and the gray whale.

Only one of the great whales is a toothed whale. It is the sperm whale, one of the most interesting-looking creatures alive. Moby Dick, the famous fictional whale, was a sperm whale. Other toothed



Les requins associes

Whales are able to spend long periods of time under water—thanks to special adaptations of their respiratory and circulatory systems that allow them to conserve oxygen.

whales are the beaked whales; the belugas, or white whales; the narwhals; the killer whales; and the pilot whales. All the dolphins are technically toothed whales, too, and the killer and pilot whales are technically large dolphins.

THE BALEEN WHALES

Ten species make up the suborder Mysticeti, or baleen whales. The word "Mysticeti" comes from the Greek word *mystax,* meaning "a moustache," and *ketos,* meaning "whale." The idea that these whales are "moustached" comes from the fringed plates of baleen that hang down from their upper jaws on either side of the roof of the mouth. The baleen, despite its sometimes being called "whalebone," is not bone at all. It is an outgrowth of the whale's skin, just as fingernails are an extension of the skin structure in a human.

Baleen used to be of great commercial value—so much so that it shared honors with whale oil as the object of whaling expeditions. In fact its value often surpassed that of oil. Although its best-known use was as corset stays, baleen was also used in bonnets, bodices, hoopskirts, umbrellas, whips, walking canes, and telephone covers. But in modern times baleen has been almost completely replaced by flexible steel and plastic.

The Mysticeti use their baleen to filter their food from the sea. Although some baleen whales will eat small fish, most feed on tiny shrimplike crustaceans known as krill. When the baleen whale feeds, it moves through the water with its mouth open, taking in huge quantities of krill and other floating animal matter. This food is swept up against the matted surfaces of the fringed baleen sheets. The whale closes its mouth and raises its tongue against the palate. Water is forced out between the baleen sheets and the loose lips, and the filtered and unchewed food organisms are pushed back by the tongue and swallowed. The food then enters a four-chambered stomach where it is slowly broken down for digestion.

It is the cool waters near the poles that support krill, which accounts for the baleen whales' summering in the high latitudes of the Arctic and Antarctic, though they migrate long distances to temperate and subtropical waters to breed and give birth in a less harsh environment.

The female baleen whale is larger than the male, and baleen whales on the whole tend to be larger than the toothed whales. Some baleen whales are faster swimmers than the toothed whales, but they do not dive as deep or stay under water as long.

All baleen whales have two blowholes, whereas toothed whales have only one. This feature makes for symmetry in the head structure of the baleen whales, and for asymmetry in the head structure of the toothed whales.

Here follow descriptions of the major Mysticeti, or baleen whales.

Blue whale. The blue whale *(Balaenoptera musculus),* or sulphur-bottom whale, is the largest animal that has ever lived. A full-grown female may reach 30.5 meters in length, and the smallest adults are 21 meters long. The adult blue usually weighs between 65 and 150 metric tons.

The blue whale's body is a dark slate-blue with white marblings on the underside. The head is flat and short, and the baleen plates are stout, stiff, and black.

The blue whale belongs to the rorqual, or finback, family. All members of this family have longitudinal grooves or furrows on their throats. These allow the throat to expand when the whale swallows. And, as one of their family names implies, they have a back, or dorsal, fin.

The blues usually travel in family groups of a bull, a cow, and a calf, or in small schools of six, but young adults are sometimes seen alone. In summer the blues are found along the edge of the pack ice at both poles.

Once the most valuable and sought-after of all whales, the blues are now nearing extinction. They have been fully protected since the late 1960s, when they were estimated to have been reduced to one per cent of their former numbers. Because they occur in scattered and isolated populations, it may be difficult for them to recover.

Fin whale. The fin whale *(B. physalus),* also known as the finback and the common rorqual, is slightly smaller and more slender than the blue. Its maximum length is 25 meters and its average length 21 meters. This whale is generally blue-gray in color, but its coloring is not symmetrical. The left side of the back is of a darker shade than the right. The right lower jaw is light on the outside and dark on the inside. The coloring of the left lower jaw is the opposite—dark outside and light inside. The first third of the baleen on the right is cream colored, while the rest is blue-gray.

The fin whales are more gregarious than the blues. A dozen fin whales together is a common sight, and they sometimes travel in schools of 100 or more. They are fast swimmers, even reaching a speed of 37 kilometers an hour at times. The fins are seen in all the cool waters of the world.

The fin whales were once the most numerous of the rorquals, but intense hunting since the mid-1940s has reduced them to one-fifth their former numbers. In 1975 the killing of the fin whale was forbidden throughout most of its range.

Sei whale. The next in size of the rorquals is the sei whale *(B. borealis).* Its greatest length is about 18 meters and its average length 13 meters. Sei whales are bluish black in color on the back, shoulders, and head, but the sides are gray. The underside has white longitudinal stripes. The baleen, which is mainly white, is quite long and very soft and fine. The throat furrows are shorter than in other baleen whales.

The sei is the most consistently swift of all whales, sometimes swimming for considerable distances at speeds of up to 35 kilometers an hour. It travels singly or in

A whale sounding. At the start of the dive, the flukes are raised in the air. Then the whale slips below the surface at nearly a vertical angle.

Giani Tortoli/PR

groups of two to five, and is sometimes found in shallow waters. With the depletion of the blue, fin, and humpback whales, the sei has been seriously overhunted and is in a major decline. In 1975 the hunting of seis was restricted but not outlawed.

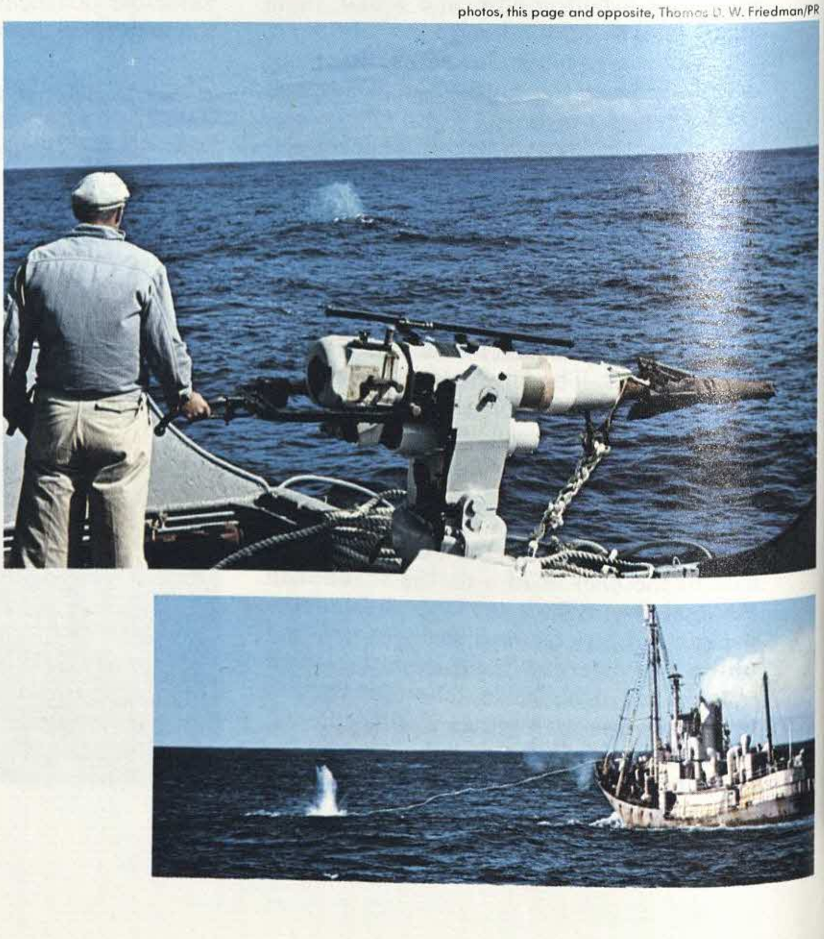
Bryde's whale. Bryde's whale *(B. edeni)* has only been recognized by whalers as a separate species from the sei whales since 1912. Its maximum length is 15 meters and its average length 12 meters. It differs from the seis in having short, coarse baleen, white in front and black at the back, and long throat furrows. Also, Bryde's whale feeds mostly on fish instead of krill.

Bryde's whale inhabits tropical and subtropical waters and does not migrate seasonally to cooler waters. It is most often seen off the coasts of South Africa. Statistical data on Bryde's whale is often erroneously lumped in with data on the seis.

Minke whale. The smallest of the rorquals is the Minke whale *(B. acutorostrata)*, also called the piked whale and the lesser rorqual. The minke is not considered one of the great whales, since it is a pygmy, reaching only 9 meters at its longest and averaging 8 meters. Its shape is that of a miniature fin whale, and its color is blue-gray on the back and white on the underside. It has cream-colored baleen and a white band across the middle of each flipper. It feeds mainly on fish.

Minkes are found in all the cool waters of the world, and in the Antarctic they often live among the ice floes or under the pack ice. They have a habit of jumping right up out of the water—an activity known as *breaching*—and doing other acrobatics. Sometimes they appear to be standing up vertically in ice holes, which they may have banged in the ice in order to breathe.

Despite their small size, the minkes are now the most hunted of the rorquals, since the other members of the family are so depleted. The meat of the minke is tasty. Much of the world's catch is eaten by the Japanese.



photos, this page and opposite, Thomas D. W. Friedman/PR

Catching a whale. A whaler waits for the whale to approach before firing a harpoon (right). Then the whale is brought to the side of the ship (far right).

Humpback whale. The humpback whale *(Megaptera novaeangliae)* belongs to a separate genus of the rorqual family. Despite its name, it is not at all humpbacked, but it is more pear-shaped than the other rorquals and has fewer and much wider throat pleats. Its maximum length is 15 meters and its average length about 14 meters. The back and sides are black in color, and the underside is usually white. The baleen is dark gray. The humpback has very long, knobby flippers and a broad, rounded snout. There are also knobs on the jaws and the top of the head, with coarse hairs sprouting from them. The humpback is plagued by barnacle parasites – sometimes as much as a half metric ton to a single whale.

The humpback whale has many engaging traits. When humpbacks mate, for example, they embrace each other with their long flippers. And they can often be seen breaching and doing back somersaults in the air. When swimming, they will sometimes roll over and slap the water with their flippers, making a loud smacking sound. The humpback has a varied repertory of "songs," and popular recordings have been made of them.

Because the humpback is a slow swimmer, lives in shallow waters, and has very thick blubber, it has been overhunted by coastal whalers for centuries and is now very rare. It has been protected since 1966.

Right whales. The right whales – the right and the bowhead, or Greenland right – are two of the most interesting species of great baleen whale. They are stout and have very big heads. They also lack throat furrows and the dorsal fin characteristic of the rorquals. The name "right whales" comes from the fact that in the early days of whaling they were considered the "right whales" to go after because they had thick blubber and long valuable baleen, were slow swimmers, and would float when dead. The rorquals and the sperm whales were the "wrong whales" – primarily because they would sink.

The right whale *(Eubalaena glacialis)*, also called the Biscay right, the black right, the North Atlantic right, and the southern right, reaches 18 meters in length. It is black in color, though there may be irregular white patches on the underside. The baleen is black, up to almost 2.5 meters long, and rather coarse. On the top of the arched upper jaw are wartlike callouses, referred to as "the bonnet," which are crawling with whale lice.

Because the right whale tends to live in coastal waters and is a slow swimmer – traveling at only between 3 and 10 kilometers an hour – is has been the easy prey of whalers and has been in decline for centuries. Although it has been fully protected since 1935, it has not made a comeback, and only about 2,000 right whales are thought to remain.

The bowhead whale *(Balaena mysticetus)* is also called the Greenland right and the Arctic right. It has black baleen averaging 3 meters in length – the longest of any Mysticeti whale. The whale itself reaches a maximum length of 18 meters and is black in color with a cream-colored patch under its chin. The upper jaws of this whale's

© Allan Morgan/Peter Arnold, Inc.

A boy reaches into the waters off Baja California to pet a gray whale.

huge head are arched into an almost semicircular bow—hence its name.

The bowhead is very near extinction. Only one population of about 1,000 remains, in the Alaskan Arctic, living near the edge of the pack ice. This whale is an active breacher and can stay under water an hour—longer than any other baleen whale.

Although the bowhead has been protected since 1935, the small surviving population is endangered by the Alaskan Eskimos, whose traditional culture is based entirely on whale hunting. Nonetheless, the latest figures suggest the number of bowhead is increasing slowly.

Gray whale. The gray whale *(Eschrichtius robustus)* makes up a third major family of baleen whales. Also called the California gray whale and the devilfish, this whale is gray in color with white flecks on the flippers and sides. It is rather small for a great whale, averaging 14 meters in length. The grays have short, thick, cream-colored baleen. The flippers are large and rounded, and the outline of four "fingers" can be clearly seen in them. Like the humpbacks, the grays usually carry many barnacles, which make their skins look mottled.

The grays travel singly or in small schools, and are known for their long, regular migrations from Alaskan waters to breeding grounds off Baja California.

The gray whales were in a serious decline until they became fully protected in 1947. They have made a remarkable comeback, and are now estimated to number around 11,000.

THE TOOTHED WHALES

The Odontoceti, or toothed whales, are probably only distantly related to the Mysticeti, or baleen whales. As we said earlier, the main way in which the toothed whales differ from the Mysticeti is that they use teeth rather than baleen for feeding. Other major differences are that the toothed whales have only one blowhole and no throat pleats; the males are much larger than the females; and the gestation period is longer than that of the baleen whales. The Odontoceti also dive more deeply and stay under water longer than the baleens do.

Sperm whale. The only great whale among the Odontoceti is the sperm whale *(Physeter catodon),* also called the cachalot. The bulls, which may be twice the size of the cows, reach a maximum length of 18 meters and an average length of 14 meters. Their color is dark gray, shading to white underneath.

The sperm whale's body is shaped like a tapering cylinder. The widest third of the cylinder is the head, which is shaped like a boiler with dents on either side. Its mouth has teeth only in the lower jaw.

The huge head encloses the largest brain of any creature alive, weighing a little more than 8.5 kilograms. It also houses a reservoir, or case, filled with a liquid wax called *spermaceti,* which gives the whale its name. This whale is chiefly hunted for its spermaceti, which was used for lamps before petroleum products became common. It is still in demand as a lubricant for fine machinery and is sometimes used in cos-

© David Muerdter/Photo Researchers Inc.

Majestic humpback whales on their Cape Cod, Massachusetts feeding grounds are a thrilling sight to a group of people on a whale-watch cruise.

metics. Ambergris, a substance used in perfume making, is found in the intestines of some sperm whales.

The sperm whale usually eats squid and cuttlefish, and dives deeply in search of its food. It can stay under water for an hour and a half.

Sperm whales often travel in herds of from 50 to several hundred. They are the only polygamous great whales. The cows sometimes travel in "harem schools" watched over by from one to four bulls, or "schoolmasters." Solitary bulls that have been driven from the herd can be aggressive—as was Moby Dick.

The sperm whale population has dropped to 25 per cent of its former numbers, but the sperm whale is only partially protected.

Bottle-nosed whale. The bottle-nosed whale *(Hyperoodon ampullatus)* is another important toothed whale. Its maximum length is 9 meters. The young are gray-black in color but develop yellowish-white markings as they grow older. The bulging forehead of the male also contains spermaceti. These whales live mainly in the North Atlantic. They are known for always assisting their wounded companions and for making very sudden, swift dives.

Narwhal. The narwhal *(Monodon monoceros),* a fascinating little whale, grows to between 4 and 5 meters long. The male is famous for its left-hand upper tooth, which grows out as a leftward spiraling tusk to a maximum length of almost 3 meters.

Because the narwhal lives in Arctic seas, it used to be taken as a secondary catch by whalers in search of the bowhead. Since the bowhead has become too rare to be hunted commercially, the narwhals are recovering.

Beluga. The beluga, or white whale *(Delphinapterus leucas),* belongs to the same family as the narwhal and, like its relative, lives mainly in the Arctic. The maximum length of belugas is 5.5 meters and the average length is about 4 meters. Young belugas are dark gray, but by age 4 or 5 they become white. They are regularly hunted by Eskimos of the Canadian and Alaskan Arctic.

Killer whale. The killer whale *(Orcinus orca)* and the pilot whale are technically dolphins but are commonly known as whales and will be discussed here. The kil-

Thomas D. W. Friedman/PR

Whale oil, meat, and other products appear in European, Japanese, and Soviet markets, but there is increasing pressure against whaling in all parts of the world.

ler whale is found the world over. The male's maximum length is nine meters. This whale has a glossy black back and white markings on the sides and belly. It also has a prominent dorsal fin that is sometimes nearly two meters high. Though the killer whale often eats fish and squid, it is famous as the only cetacean that also eats meat, and its mass attacks on other, larger whales, and on dolphins, baby seals and walruses, and penguins are well known.

Pilot whale. The pilot whale, or blackfish (*Globicephala melaena*), measures anywhere from 3.5 to 8.5 meters in length. It is black and has a rounded head. This whale, one of the most intelligent and friendly of the dolphins, lives in northern waters but has relatives the world over. Pilot whales travel in large herds, and since they tend to "follow the leader," the whole herd sometimes runs aground while following a sick or confused member.

WHALING AND ITS CONTROL

Although whales were probably hunted long before recorded history, the earliest whaling of which we have records was carried on by the Phoenicians in the eastern Mediterranean about 1000 B.C. Much later, in the 10th century A.D., the Basques of the Spanish Atlantic coast learned to be expert whalers. As they became more and more practiced, their quarry, the Biscay right whale, became nearly extinct.

When the English and the Dutch began to hunt whales in the 1600's, they hired Basques to teach them their techniques. The English and the Dutch based their rival whale fisheries on Spitsbergen, off the Arctic coast of Norway, and they hunted the bowhead whale to the verge of extinction.

The great American sperm whale fishery, based chiefly on such New England ports as Nantucket Island and New Bedford, Massachusetts, began in 1712 and lasted until petroleum products replaced spermaceti, beginning in 1859. The resulting decline in sperm whaling saved the sperm whale from depletion at that time.

The rorqual fishery of the sub-Antarctic oceans, begun in the 1920's, became the next link in the chain of overkill and decline. By this time, the use of the harpoon gun (a harpoon with an explosive charge at the end) and the factory ship (a floating slaughterhouse) had made whaling too efficient to give the whale a fighting chance.

In 1935 an international whaling convention forbade the taking of the right whale and the bowhead.

In 1946 whaling interests in 20 nations formed the International Whaling Commission. A voluntary body, it had as its original aim the protection of whales for the "orderly development of the whaling industry."

Although the IWC placed prohibitions on the killing of species, such as the blue, that are near extinction, its efforts to preserve other species from decline were only partly successful. In its early years it set catch quotas too high, which resulted in more whaling rather than in less. Later, efforts to place a moratorium on all whaling were unsuccessful.

In 1982, however, the IWC, by then grown to 39 members, voted a worldwide ban on all commercial whaling for an indefinite period beginning in 1985. The major whaling nations resisted the ban. Japan and Norway invoked their sovereign rights to continue whaling within a 320-kilometer coastal zone, and the Soviet Union indicated that it might leave the commission in order to continue hunting less-threatened species.

Isy-Schwartz

Dolphins are sometimes called "little whales." Like their whale relatives, they are mammals adapted to life in the sea.

DOLPHINS

People traveling by ship sometimes see fishlike creatures leaping about in the sea. Often these creatures come so close to the ship and travel along with it so faithfully that they are said to be "escorting" it. However, these friendly creatures are not fish. They are dolphins, sea-dwelling mammals classified with whales in the order Cetacea.

People often wonder whether to call these little whales "dolphins" or "porpoises," and the terms are often used interchangeably. "Dolphin" is the better term, since it applies to all the members of the group. Porpoises are actually a special type of smallish dolphin that has a rounded snout rather than the "beak," or extended mouth structure, that most other dolphins have.

Dolphins were considered sacred by the ancient Greeks, and were described by the Greek philosopher-scientist Aristotle. But in ancient times—and, in fact, up until the late seventeenth century—dolphins were thought to be fish because of their fishlike shape, their fins, and the fact that they live entirely in the water. However, when scientists began to classify animals according to similarities in their structure and function, it became clear that dolphins are mammals. They are warm-blooded, give birth to live offspring, and suckle their young. And, though they live in water, they breathe through lungs and must come to the surface for air.

Like the whales, dolphins are the product of gradual adaptation to life in the sea by a former land-dwelling animal. And, also like the whales, the dolphins have large brains and are highly intelligent.

Another trait dolphins share with whales is the ability to produce high-pitched sounds, or "songs." Dolphins use their sound equipment to signal to one another and to locate food—usually fish or cuttlefish—and other objects through a process known as *echolocation.* In this process the dolphin's sounds echo off, or bounce back from, distant objects, letting the dolphin know where the objects are located.

Since the early 1900s, scientists have been learning how to keep dolphins in captivity and have been studying them more and more closely. Now they are concentrating their researches on dolphin intelligence and on how and why the dolphins produce their complicated sounds.

But even as we are learning to appreciate the sophisticated life and behavior of dolphins, over 100,000 dolphins a year are being killed. The spotted dolphin, the spinner dolphin, and the common dolphin habitually swim with the yellowfin tuna, which are taken in special nets called purse seines. The tuna fisherman set the nets under the schools of tuna, and when the nets are closed and hauled in, many dolphins are trapped. The dolphins, which are air-breathing animals, may drown in the nets, or, once on deck, die of exposure.

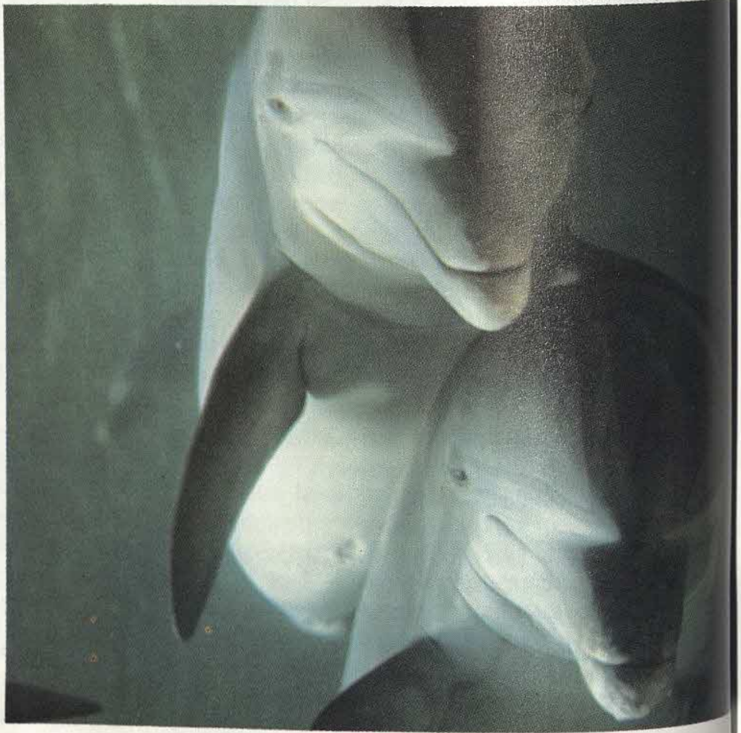
In 1972 the U.S. Congress passed the Marine Mammal Protection Act. It sought to oblige the U.S. tuna industry to seek methods of seining that would reduce the killing of dolphins. But the tunamen have resisted complying with the law and are trying to get Congress to remove its restrictions.

A MAMMAL IN THE SEA

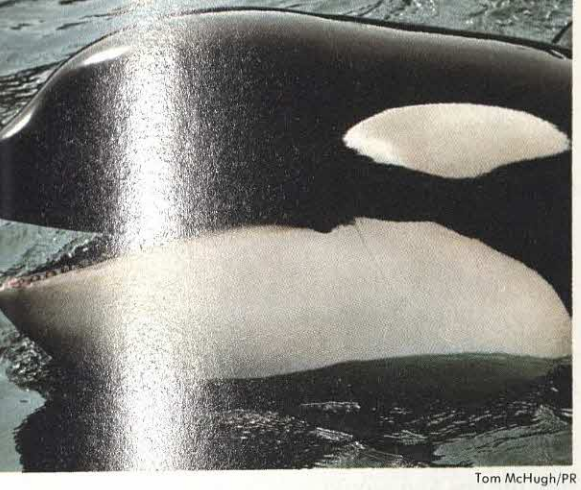
The classification of dolphins is somewhat confusing. Technically, all dolphins belong to a suborder of whales known as the Odontoceti, or "toothed whales." Most dolphins are classified in the superfamily Delphinoidea, a large group that also includes two species called whales—namely, the killer whale and the pilot whale. River dolphins, which are somewhat different from most other dolphins in appearance and habits, are classified in the superfamily Platanistoidea.

The dolphins' ancient ancestor completed the transition to life in the water perhaps as much as 70,000,000 years ago. By the time the former land animal had become completely water dwelling, its body had undergone great changes. The forelegs had become flippers, in which the traces of five "fingers" can still be observed. The hind legs disappeared, and the tail became modified into tail flukes, with which the animal propels itself through the water. The body had become generally streamlined to permit fast swimming—up to 35 kilometers per hour in some species. The nostrils had migrated to the top of the head to form the sin-

Marineland of Florida



The two bottle-nosed dolphins at the right are just as interested in their photographer as the photographer is interested in them.



Tom McHugh/PR

A killer whale. Killer whales are really dolphins—unusual dolphins in that they are larger and more aggressive than typical dolphins are.

gle *blowhole* through which the dolphin breathes. The fur had been lost and a layer of blubber had developed just under the skin as a more efficient means than fur of keeping the animal warm in the water. The sense of smell had been almost totally lost, and the eyesight had diminished. And, while the outer ear had vanished, a highly sensitive inner ear had been developed.

The dolphin's sensitive hearing is important in the animal's echolocation system, which we mentioned earlier. The dolphin emits sounds, either through its blowhole or by passing air over its larynx. The sound waves emitted bounce off distant objects and return to the dolphin, in varying tones and at different times. These waves set up vibrations in the inner ear. These vibrations tell the dolphin the exact location of undersea objects, including food.

Other major changes in the dolphin's internal functioning had also occurred by the time it took up full-time life in the water. The mechanics of breathing had altered considerably to allow the dolphin to spend more time under water. After the dolphin inhales, 40 per cent of the oxygen taken in finds its way into the muscle tissue. (By comparison only 13 per cent does so in humans.) Because of this efficient uptake and the muscles' ability to store and then release oxygen as needed, dolphins require oxygen from the air less frequently than humans do.

The dolphins' lungs themselves are efficient users of oxygen, for they can exchange 85 to 90 per cent of their oxygen with each breath. A person must breathe twelve to sixteen times a minute, whereas a dolphin of the same size need only breathe an average of one to three times a minute.

Dolphins have also developed a special system of blood vessels to offset sudden changes in their blood pressure that occur when they dive. In these special networks, called the *retia mirabilia,* blood flow is not limited to one direction, as it is in most blood vessels; instead the blood can flow in either direction. This enables a dolphin to shunt its blood away from any area where the blood pressure rises sharply and later allow the blood to return.

Despite these changes in physiology needed for an active life in the water, dolphins, as we have mentioned, retain the basic traits of mammals. One, which we have just discussed, is mammalian lungs, which require them to surface at intervals to breathe air. But there are two ways in which the cetacean lung differs from that of other mammals. The passage from blowhole to lung is direct and relatively short. And the respiratory system has muscular valves that safely close off the blowhole and bronchial tubes when the animal dives.

DOLPHINS AND THEIR YOUNG

Other traits also identify dolphins and other whales as mammals. The main one

With its seeming grin, this spotted dolphin reveals the many pointed teeth that make it a member of the suborder of toothed whales.

Russ Kinne/PR

Douglas Faulkner/PR

Dolphins are often seen traveling alongside ships. Records of this activity go back to ancient times.

is that they bear live offspring and suckle their young. The gestation period for dolphins is 10 to 12 months. The young are fully developed at birth and may be quite large—sometimes half the length of the mother and up to one sixth of her weight. There is usually only one young.

When the female dolphin is about to give birth, she begins to swim more slowly than usual. Some of the other female members of the school stay close to her, probably to offer help and to prevent her being separated from the school. When the young dolphin emerges from its mother—always tailfirst—one of these "aunts" escorts it quickly to the surface so that it can take its first breath of air. While the calf, as the offspring is called, remains young, one of the aunts swims beside it on the opposite side from the mother, so that it is protected on either side.

The mother dolphin suckles the calf for a year or more. The calf nurses under water, where the mother squirts milk directly into its mouth by means of a muscle associated with the mammary gland. Dolphin milk is very rich in fats and proteins, and the calf grows rapidly. Despite this rapid growth, however, sexual maturity is reached at very different ages in different dolphin families. The common porpoise is sexually mature by 15 months of age. But the bottle-nosed dolphin only reaches sexual maturity at 5 years of age.

INTELLIGENCE AND BEHAVIOR

Many ancient peoples, and especially the Greeks, accepted the fact that dolphins were nearly as intelligent as humans. They readily believed stories of heroic acts by dolphins and of remarkable friendships that occasionally developed between dolphins and human beings—usually young boys.

According to one legend, Telemachus, the son of the Greek hero Odysseus, fell into the sea and would have drowned had a dolphin not discovered him and pushed him to shore. Thereafter Odysseus carried the picture of a dolphin on his shield. This story was recorded by the Roman writer Plutarch and is the earliest known account of a dolphin's helpfulness to a human.

An early story of a dolphin-human friendship is told by the Roman scientist Pliny in his *Natural History*. In a lagoon in Italy there lived a dolphin who became the friend of a young boy. This boy had to walk all the way around the lagoon every morning to get to his school in the town of Puteoli. After a while the dolphin began to let the boy ride on his back, and at last began to carry him all the way across the lagoon to school each day. Not only that—the dolphin soon began calling for the boy after school so that he could carry him back home again.

As the modern scientific age dawned, scientists tended to downgrade animal intelligence. But more recent studies, begun in 1938 at Marineland, Florida, and continuing there and in other centers all over the world, indicate that dolphins may indeed have a very high intelligence level.

It is well known that dolphins can learn many complicated tricks from their keepers. But what reveals dolphin intelligence more clearly is the games they invent for themselves and then "teach" to humans. A game of "catch" with an inner tube was invented by some dolphins in an aquarium, but it took a human onlooker whom they were trying to interest in the game some little time before he understood that he was supposed to return the inner tube that was being repeatedly tossed at him by the playful dolphins.

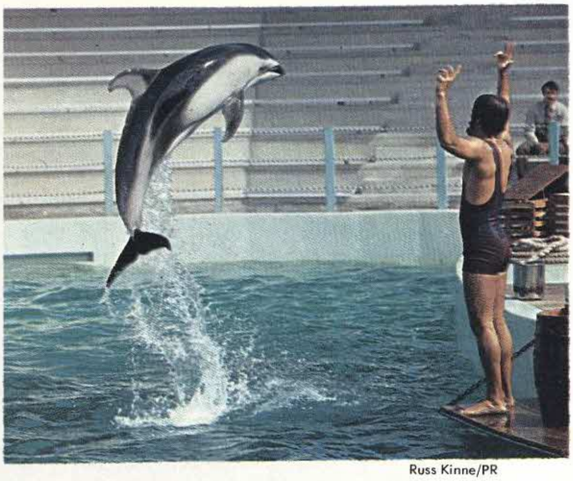
The dolphin's brain is large (larger than the brain of man) and has many convolutions, or folds, that increase its surface area, where brain cells are found. The ability to learn and invent games, together with the structure of the dolphin's brain, strongly indicates intelligence. But perhaps the clearest indication is given by the "dolphin language." Language involves the understanding of symbols and their repeated use to express a particular idea and communicate it to other members of the species. Words are the symbols of our language. Are the sounds of the dolphin the symbols of a dolphin language?

A DOLPHIN LANGUAGE

Dolphins make many different kinds of sounds, or vocalizations, sometimes referred to as "beeps," "whistles," and "clicks." Some of these sounds are within the range of human hearing, and others are outside of that range. We have already described the dolphin's use of its own sounds in the process known as echolocation. But much research is aimed at finding out if and how dolphins use these sounds to communicate with one another. Scientists are quite sure that some calls are attempts to keep the school together, and perhaps to warn of danger.

A recent experiment done with sperm whales, who are close relatives of the dolphins, may shed some light on the vocalizations of dolphins. Some researchers working in the Pacific Ocean managed to separate a sperm whale calf from its mother. Before reuniting the two, the researchers recorded the pitiful wails of the young whale, presumably crying for its mother and its herd. The calf also emitted regular high-pitched "beeps" that sounded nothing like its other cries. The two kinds of sounds seemed to be produced by different organs of the body and to be sent for different purposes. The exact purpose of the "beeps" remains to be learned.

John C. Lilly, a neuroresearcher, has been working for some years to discover the secrets of the dolphins' sounds. He reports that he has also succeeded in getting dolphins to imitate some English words, though the dolphins sometimes "speak" too fast to be understood by the human ear. Although Lilly has not as yet proved that dolphins can produce two-word sentences on their own, which is the basis of a thought-carrying language, he has high hopes of learning more about dolphin communication in the future.



Russ Kinne/PR

Dolphins seem to enjoy learning tricks. This white-sided dolphin leaps on command.

DOLPHINS LIKE COMPANY

Dolphins appear to be highly emotional animals and can form deep bonds of affection both with other dolphins and with humans. Moreover, when dolphins are forced to be alone, they suffer. When dolphins were first kept in captivity, a single dolphin would usually be kept in a tank by itself. The dolphin, isolated from its fellows, and without any meaningful human contact, would pine away and die. Experts studying this phenomenon learned that the lonely and bored dolphin would refuse to eat, thus committing dolphin suicide. Now if a dolphin must be kept alone, long daily visits from a human being are scheduled, which include games and other joint activities.

Dolphins are among the most playful creatures in the world, and it appears to be this natural, boisterous contact with other creatures that keeps them both alert and alive.

SOME KINDS OF DOLPHINS

There are many species of dolphin. We have chosen just a few of the most typical, most common, and most interesting to describe in detail.

The common dolphin *(Delphinus delphis),* also called the crisscross, the white-belly, and the saddleback, frequents all the world's temperate oceans. It is the dolphin most often seen cavorting around ships in mid-ocean and is certainly the dolphin that was so well known to the ancients. It is less than 2 meters long on the average, but can reach 2.5 meters. The skin has beautiful markings. The back is black or dark brown, and the belly white. On each side there are wide bands of yellow, gray, and white. There is also a distinctive black marking around each eye and across the "bridge" of the beak. The beak is somewhat narrower than that of the bottle-nosed dolphin.

The bottle-nosed dolphin *(Tursiops truncatus)* is the most common dolphin in the seas off eastern North America. It is this dolphin that is usually seen in East Coast aquariums and which has been so carefully studied at Marineland, Florida.

This dolphin averages 2.5 meters in length, but can reach 3.5 meters. The back is usually a darkish gray and the belly white. It has a short but distinct beak.

Risso's dolphin *(Grampus griseus)* is a large dolphin, reaching anywhere from 3.5 to 4 meters in length. Its beak is not at all pronounced. Its skin, which is often bluish-white tinged with purple and yellow, is marked by irregular scratchlike lines.

A Risso's dolphin named Pelorus Jack used to escort ships across Cook Strait, New Zealand, between the cities of Wellington and Nelson. He kept up his escort services for 24 years, from 1888 to 1912. Pelorus Jack became a legend, and some people considered his presence a gift from God, guaranteeing safe passage. This belief was so strongly held that a steward serving on a ship avoided by Pelorus Jack asked for transfer to another vessel. As it turned out, the steward acted wisely, for the shunned ship later sank, with a loss of 75 lives.

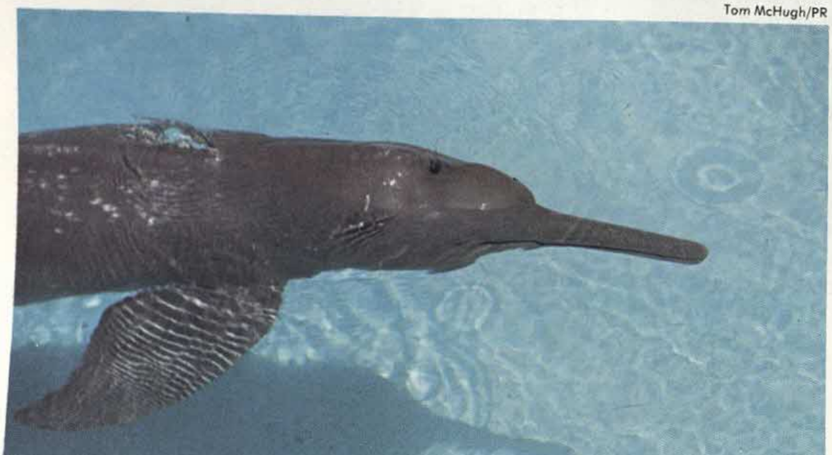
The common porpoise *(Phocoena phocoena)* is also called the harbor porpoise because it lives in coastal waters and often enters harbors and rivers. In the United States, it is found only along parts of the Pacific coast. This animal is usually about 1.5 meters long. It is usually black above and white on the underside, though it may be all black. It has a rounded snout typical of porpoises rather than a beak. The common porpoises used to be eaten by Europeans as a delicacy.

The Dall porpoise *(Phocoenoides dalli)* is a near-shore species found off Japan, Alaska, western Canada, and the western United States. It is larger than the common porpoise, often reaching a length of 2 meters. It is jet black except for striking white markings on the sides, extending upward from the white belly.

The Amazonian dolphin *(Inia geofrensis),* or boutu, is one of the river dolphins. River dolphins inhabit fresh water and are far less streamlined than the true dolphins. They have long beaks with ferocious-looking teeth. Their eyes are tiny and their eyesight is very poor. They live by digging into the river mud for fishes and crabs, and can move in shallow water.

The Amazon dolphin is usually dark when young, getting lighter to a grayish-white, sometimes pinkish, color with age. This dolphin grows to a length of 2 meters. The river dolphins are thought to be a more primitive form than the saltwater dolphins.

Tom McHugh/PR



The Amazonian dolphin lives in muddy river waters. River dolphins have very long beaks and small eyes.

Jeff Foott

The manatee inhabits warm-coastal water, feeding on seaweed and fresh-water plants.

SEA COWS

Several times, in the long history of the mammals, species that once lived entirely on land have changed their habits and taken to the water. Some of them – including the sea cows – have become completely adapted to life in the water. Even though as mammals they must come to the surface to breathe, they spend all their lives in the water, and if they become stranded on land they die.

COUSINS OF THE ELEPHANT

There are two families of sea cows – manatees and dugongs – making up the order Sirenia. Sea cows are probably descended from a land-dwelling, vegetation-eating mammal that was also the ancestor of the elephants. We do not know what this ancestral animal looked like. Nor have any fossils been found that would reveal the stages by which the later ancestors of the Sirenia progressed from the land to the rivers and seas. But we do know that by 50,000,000 years ago there were Sirenia-like creatures.

In the sea cows we can see the special physical traits that slowly evolved to make life in the water possible for a former land animal. They developed massive but tapering bodies, which enable them to move through the water with relative ease. Their forelegs have become well-developed flippers used for steering. All traces of external hind legs have been lost. The hind end now terminates in a horizontally flattened tail, the up-and-down movement of which furnishes thrust in swimming. The tail of the manatee is rounded, whereas that of the dugong is crescent-shaped. In spite of these fishlike characteristics, however, sea cows are true mammals and have certain characteristics typical of mammals. They breathe with lungs, for example, bear live offspring, and suckle their young.

CHARACTERISTICS OF MODERN SEA COWS

The order Sirenia takes its name from the siren, or mermaid, of medieval legend, a creature then identified as having a woman's upper body and a fish's tail. Some people, however, believe that the legend of the siren may have been based on the appearance of the sirenians. From a distance the sirenians have a somewhat human look, for they sometimes stand erect in the water, supported by their tails. Moreover, their heads may be draped with loosened vegetation that resembles long hair. And the females suckle their young in an almost human fashion, holding the baby up to the breast in a crook of the front flipper. (In classical Greek legend a siren was a creature with a woman's head and a birdlike body, but later legends identified sirens with mermaids.)

The head of a sea cow has heavy, bristly jowls with nostrils set at the top of a triangular-shaped muzzle. The nostrils are fitted with valves that can be closed in order to keep out water when the animal dives below the surface. The animals may remain under water for some time—as much as sixteen minutes in the case of the manatee.

Both the dugong and the manatee have tough, leathery skin. The brain is small. The eyes are tiny, and there are no external ears. The sense of smell is limited.

Sirenians feed on vegetation along ocean coasts or in rivers. Young dugongs and manatees are born in the water. They are nursed at the mother's teats, located high on her chest.

MANATEES

There are three species of manatee. The northern, or American, manatee *(Trichechus manatus)* is found along the Atlantic coast of the Americas southward from Florida, around the Caribbean, to the mouths of the Amazon and Orinoco rivers in northeastern South America. This slow-moving, friendly creature has been slaughtered almost to the point of extinction. Fortunately, efforts have been made to protect manatees in Florida.

The Brazilian, or Amazonian, manatee *(T. inunguis)* is found only in fresh water, on the upper courses of the Amazon and Orinoco river systems. The third species, the West African manatee *(T. senegalensis),* lives along the coast of West Africa, in the major rivers of that area, and as far inland as Lake Chad.

Manatees are usually between 2.5 and 4 meters long. Most of them are able to live equally well in fresh, brackish, or salt water. They travel in small bands and remain near shore, feeding on various aquatic plants. The upper lip of the manatee is split down the middle, and the two halves, which are strongly muscled, work against each other in cropping plants. The front flippers are used to stuff the vegetable material into the mouth. The food is then chewed slowly. Adult manatees lack front teeth but have molar teeth that are continually replaced from the back end of each tooth row.

A single young manatee is born after a gestation period of about one year. The young are born in the water, but immediately after birth the mother carries the little animal on her back, completely out of the water, for some 45 minutes. Then, over a two-hour period, she submerges it.

DUGONGS

The dugong *(Dugong dugon)* inhabits the waters along the coasts of the Indian Ocean, from central East Africa to Indonesia and northern Australia. Dugongs were once found in large herds, but they have been ruthlessly hunted for their meat and fat and are now greatly reduced in numbers.

The dugong grows to between 2.5 and 3 meters long. Unlike the manatee, it is almost strictly ocean dwelling and does not swim very far up rivers. Dugongs are sluggish animals, drifting with the tide back and forth in shallow waters where they feed. A dugong crops seaweeds and other aquatic vegetation by wrapping its whole extended upper lip around the material, pressing it against the lower lip, and pulling it away. Dugongs also differ from manatees in that they apparently do not use their flippers in feeding. They have a few peglike crushing teeth and a horny pad in the lower jaw for chewing. The males have a pair of upper tusks formed from the incisor teeth.

An unusual dugong, the Steller's sea cow *(Hydrodamalis stelleri),* once lived in the Bering Sea between Russia and Alaska. It was discovered in the eighteenth century and was hunted to extinction in just 27 years. The Steller's sea cow was enormous, reaching a length of 9 meters and often weighing as much as 3.5 tons. It was the only modern sirenian found in cooler seas.

Norman Tomalin/Bruce Coleman Inc.

The dog family includes both wild species, such as these South American maned wolves, and domestic pets. The maned wolf is not a wolf, but a fox.

THE DOG FAMILY

When we speak of dogs, we generally think of domesticated dogs, numbering over one hundred different breeds. These breeds range in size from the big Newfoundland, with its shaggy coat, to the small, hairless chihuahua. In this article, however, we shall use the phrase "dog family" in the sense of animals belonging to the family Canidae. In this group we find not only domesticated dogs but also wild dogs, wolves, foxes, and jackals.

FAMILY HISTORY

The dog family has had a long and interesting history. One of the earliest direct ancestors of the group was the small animal known as *Cynodictis,* which lived about 35,000,000 years ago. It had a long, flexible body and a long tail. Its legs were rather short and the claws on its short, spreading feet were probably retractile, or capable of being drawn back. *Cynodictis* was in all likelihood a tree dweller. *Cynodictis* had a larger brain, in proportion to its size, than other primitive carnivores. From *Cynodictis* and animals similar to it have descended the modern members of the dog family.

The early dogs gradually departed from the tree-dwelling habits of their forebears and took up their abode in open plains country, where they hunted in packs. They had to be fast in order to capture other plains animals. Hence, in time their legs were lengthened, and they developed endurance for running great distances. The thumb of each forefoot and the big toe of each hind foot were greatly diminished in size. The claws became blunt and could no longer be drawn back.

Like cats, dogs possessed shearing teeth, or *carnassials,* for slicing through tough fibers in the flesh of their prey. But, unlike cats, the members of the dog family retained certain molar teeth for chewing hard foods. Because of these grinding teeth,

C. C. Lockwood/Bruce Coleman Inc.

A red wolf: many species of wolves are threatened with extinction, in spite of their adaptability.

the members of the modern dog family have a much more varied diet than do cats. The European red fox, for example, adds snails, insects, and berries to its usual diet of small rodents.

There were several different lines of dog evolution. One line led to the now-extinct hyenalike dogs that once roamed over the plains of North America. Another branch terminated in large bearlike dogs, which also have become extinct. The wolves, jackals, foxes, and domesticated dogs formed still another group – the modern dog family – which is now distributed throughout the world. The Cape hunting dog of Africa, the dhole of India, the Malay wild dog, the Siberian wild dog, and the Brazilian bush dog are other representatives of the family.

DOMESTICATION

The dog family has given mankind an important animal ally and companion – the domesticated dog. This "friend" of man has been taught to track game, draw sleds, and guard.

According to a commonly accepted theory concerning the development of domestic dogs, these useful animals were probably descended principally from wolves, with various other wild canines contributing to the strain.

The first wolves that became domesticated were the best animal friends that man could have had for the protection of his flocks and family from the rest of the wolves. If domesticated wolves attacked wild wolves, it was perhaps because most animals acquire what may be called the *proprietorial sense*. When they have taken up their quarters somewhere, they resent intrusion. This sense of proprietorship is as strongly developed in the dog as in any other animal. The dog will often fight courageously in defense of its master's home – an instinct that finds its counterpart in the wolf's resentment of intrusion on its den.

The wolf that early man had trained from the time it was a puppy would probably attack other wolves that it might meet near the home of its master. To be sure, sooner or later the trained wolf might desert and rejoin its friends of the forest. But its cubs, born in the master's house, would be more likely to remain faithful and to become trusted guardians.

WOLVES

At one time wolves abounded in many countries where they are now scarce or unknown. They were not exterminated in England until the sixteenth century. They continued to dwell in Ireland and Scotland until the eighteenth century. In the United States wolves are quite rare east of the Mississippi but still flourish in considerable numbers in the wilder regions of the western United States south to Mexico. They are also found in the northern and western Canadian forests and in Newfoundland and the Hudson Bay region. Wolves are not found in South America or Africa.

The true wolf, *Canis lupus*, occurs over almost all of Europe except for the thickly populated areas. It is found in large numbers in the Soviet Union and in Scandi-

The gray, or timber, wolf ranges from northern Mexico to the Arctic. A very close relative is also found in Europe and northern Asia.

Dick Hanley/PR

navia. In Asia it is distributed widely to the borders of India and the plains of China. The chief representatives of the wolf tribe in India are, however, two smaller animals – the woolly wolf of the Himalayas in Kashmir and the Indian wolf of peninsular India. The brown-colored Indian wolf, which dwells on the plains, seldom hunts in large packs.

The wolves of North America include the gray, or timber, wolf, the black wolf of Florida, the red wolf of Texas, the dusky wolf of the central plains, and the coyote. In the Arctic regions we find the arctic wolf, which is nearly pure white, with a tail that is tipped with black.

The gray wolf, or timber wolf, of North America is much the same animal as that of Europe and northern Asia. Zoologists believe it to be a single, wide-ranging, adaptable, and variable species. A full-grown specimen measures 150 centimeters from the muzzle to the end of the tail, which is itself about 40 centimeters long. The height at the shoulders is about 70 centimeters; the weight is something like 70 kilograms. These are the measurements of a large male, the female being considerably smaller. The normal color seems to be a yellowish white. The underfur is gray. Many of the hairs are tipped with black. The animal has brown markings on the ears and about the face. The coat is quite variable, however, in color. It may be blackish in southern specimens.

The gray wolf once ranged throughout the whole continent. Civilization has driven it to the northern and western regions. It abounds on the plains, in the Rocky Mountains and western coast ranges, and throughout the forests of northern Canada.

The wolves of both Europe and North America frequent open country and forests. They make their *lair* in rocky caverns or in the decayed trunk of a fallen tree. Occasionally they make burrows in the ground or enlarge those begun by other animals. When the wolf lives near settled areas, it may attack flocks of sheep to obtain food. Wolves rarely attack humans. This occurs only when they are ravenously hungry or protecting wolf cubs. Generally, wolves are shy and avoid contact with people. There have been authentic cases of travelers being attacked by wolves, but a good many of the stories that have been told have been highly exaggerated.

Every year the wolf's chances for survival in a hostile world become more precarious. Wolves have successfully resisted extermination thus far partly because they can exist on a highly varied diet and partly because they have a high birthrate. The female wolf gives birth to six to ten cubs at a time and raises them all carefully so that many survive. Wolves also survive because of their tightly knit social organization. They frequently hunt in packs led by their dominant members.

However, in spite of their highly adaptable way of life, some species of wolves are now seriously endangered. In the United States and some other countries, the killing of certain species is forbidden by law.

The coyote, a smaller version of the gray wolf, hunts alone or in packs. Coyotes are becoming scarcer, in part because of campaigns against them by ranchers.

Wildlife Unlimited/PR

COYOTES

The coyote is a smaller sort of wolf. It is the New World version of the jackals and other wild dogs of semitropical parts of the Old World. Though it is often referred to as the "red wolf," the coyote shows the same gray tone as the gray wolf and has the same darker varieties. The real distinction is that of size. The coyote, or prairie wolf, is much smaller than the gray wolf. The length of a large male is rarely more than 120 centimeters, of which some 35 centimeters represents the tail. The weight averages about 13 kilograms for the male and 11 kilograms for the female. Coyotes vary greatly. Some taxonomists have established a dozen or more species and subspecies in North America.

These small wolves are restricted to the open regions of western North America, where they live in burrows and feed on mice, gophers, rabbits, and the like.

Coyotes are pests to sheep herders and poultry raisers, and there have been widespread campaigns for many years to reduce their numbers. Such campaigns are not really justified. Coyote raids on livestock can be controlled by wire fencing, which coyotes avoid. It should also be remembered that the coyote helps control vegetation-destroying rabbits.

Coyote numbers have decreased considerably, and some authorities believe that the animal may be in some danger of extinction in the near future. This possibility is increased by the fact that the coyote's natural prey – the prairie dog – is becoming increasingly scarce.

JACKALS

In Africa, the wolves are replaced by jackals. The Abyssinian wolf, red jackal, or cuberow, is a wolflike animal but slightly smaller and rather long-legged. It is bright reddish-brown with white underparts, and the bushy, 30 centimeter-long tail is tipped with black. The Egyptian, or wolflike, jackal is another large canine similar to the wolf. Its home is northern Africa, where it hunts small antelopes, mice, hares, and ground birds. It also raids livestock. The animal is buffy-brown or pale reddish in color.

Jackals are generally small, and richly colored. They have bushy tails. They are graceful animals, fortified with great endurance that allows them to travel quite rapidly over long distances. Their highest running speed is something like 55 kilometers per hour. They are, for the most part, confined to Africa, but the Oriental, or common, jackal inhabits not only north-

Jackals are usually small, graceful, and richly colored, like this silver-backed jackal. They are scavangers, with a keen sense of smell and great endurance.

M. Philip Kahl/PR

eastern Africa but also southeastern Europe, ranging eastward to India, Sri Lanka, and Burma.

Jackals eat all types of foods—in fact, almost anything at hand. They have a keen sense of smell for nosing out all sorts of refuse, and they serve as scavengers in and about villages and towns. Jackals hunt in packs, mainly on the plains, bringing down antelopes, sheep, and goats. Solitary hunters will forage for mice and other small mammals. Vegetable food also makes up part of their diet. It is a known fact that jackals follow lions, leopards, and tigers and eat what remains after these mighty hunters have had their fill. Lions, at least, apparently do not resent the company of jackals, as long as these wild dogs refrain from seeking a share of the meal until the lions have finished eating.

The common jackal is small, standing about 40 centimeters at the shoulder. It is a pale reddish or yellowish color with dirty-white underparts. Like other jackals, it hides by day and begins to roam about at dusk and on through the night. Packs of these animals enter villages where they do scavenger service but also make general nuisances of themselves by thieving food from unguarded shops and homes. A female common jackal has a gestation period, or period of carrying her young in the womb, of around nine weeks. There are from five to eight young in each litter.

The side-striped jackal is similar to the common jackal in color but wears a slanting, light-colored stripe on each side between the ribs and the hip. Its muzzle is more pointed, and its tail is usually tipped with white. The jackal occurs from the Republic of South Africa to Ethiopia, Morocco, and Senegal. The handsome black-backed jackal of west Africa is a reddish animal with a yellowish-white belly. The back is black, spotted with white or gray. The legs of this jackal are somewhat short compared to those of the common and side-striped species. All of these jackals possess a gland at the base of the tail, which discharges an offensive-smelling secretion.

DINGOES

Australia's native dog is the dingo, or warrigal, a medium-sized, reddish-yellow animal. It is the only large wild mammal that is not a marsupial, or pouch-bearer, in Australia. In more populated areas where dingoes readily cross with domestic dogs, a pure-bred dingo is seldom seen. Small packs of wild dingoes, pairs, or even lone individuals hunt in the forests and open plains. Dingoes find lairs in crevices

Wild dogs, like this mottle-coated species in the Serengeti National Park in Africa, are ferocious hunters.

G. Schaller/Bruce Coleman Inc.

among rocky outcrops, in ground burrows, or in hollow logs. From five to eight pups are borne by the female at one time.

We are not entirely certain about the manner in which this animal came to be an inhabitant of Australia, where the other mammals are so different. It was first maintained that the dingo was a recent importation. This theory was apparently upset when fossil remains of the animal were found in Australia, together with the fossils of marsupials, in Pleistocene deposits going back about a million years. Did this discovery indicate that the dingo evolved independently, together with marsupials and the other unusual animals of the island continent? Modern biologists are inclined to believe that the dingo was an importation after all. It was probably introduced to Australia by prehistoric man.

When settlers came to Australia, the dingo did not represent much of a problem. However, the introduction of the rabbit changed the situation. Rabbits increased and multiplied, and so did dingoes, which preyed upon the rabbits and therefore were assured a staple food supply. Unfortunately, the dingo also turned its attention to sheep and poultry and became a menace to the stock raiser and farmer.

The native Australians hunt the dingo for food. Often, too, they seek out the young dingoes in their lairs, and they bring up these wild dogs as domestic animals.

DHOLES

Among the most remarkable hunters of the dog family is the dhole, the wild dog of India. This animal has a distinctive red coat. It weighs about 20 kilograms and has an over-all body length (including the tail) of almost 120 centimeters. In India, dholes are found in wooded areas. Where there are no forests, as in Tibet, the animals dwell in the open country.

Dholes hunt in packs. Possessed of a keen sense of smell, they can track a quarry by scent until they are close enough to keep it in view. One of the dholes acts as a sort of "master of the hunt". It keeps in the lead and prevents the pack from scattering by emitting a series of sharp yelps. When the quarry, say a deer, is at bay, the dholes circle it and soon overpower it. Deer are the favorite prey of these animals. Dholes also attack wild pigs, goats, and even such animals as bears, leopards, and fully grown buffaloes. Popular belief in India has it that dholes sometimes hunt tigers. There is no conclusive evidence for this, but tigers and

The gray fox, found in Canada, the United States, and Mexico, is nocturnal and preys on rabbits and mice.

Leonard Lee Rue III/Bruce Coleman Inc.

dhole packs may sometimes fight over the possession of a slain deer or goat.

In the breeding season, the packs are dissolved for a time. The female dhole has from four to six pups, after a gestation period of about nine weeks. When the young are weaned, they are fed with partly digested food that the mother has regurgitated, or cast up from its stomach.

CAPE HUNTING DOGS

The African, or Cape, hunting dog (genus *Lycaon*) also hunts in packs. It is a strong animal, with a big head, powerful jaws, and long legs. Its overall length is approximately 120 centimeters. The large, oval ears are rather like those of the hyena. For this reason, the animal is sometimes known as the "hyena dog." The basic color of the coat is generally tortoise-shell, mottled with yellow, black, and white patches. Occasionally one comes upon black specimens of this striking animal.

Cape hunting dogs hunt in packs numbering from twenty to sixty. They prey on antelope, hartebeest, and other animals dwelling in the brush country south of the Sahara. The dogs are always on the move and travel great distances. They communicate with one another by musical calls. When surprised, the Cape hunting dog barks angrily. At night, it sometimes makes chattering sounds.

Although Cape hunting dogs can swim very well, they will not cross deep water, possibly because of the danger of lurking crocodiles. It is said that antelopes sometimes make good their escape from a pursuing pack by jumping into the water of broad rivers or ponds.

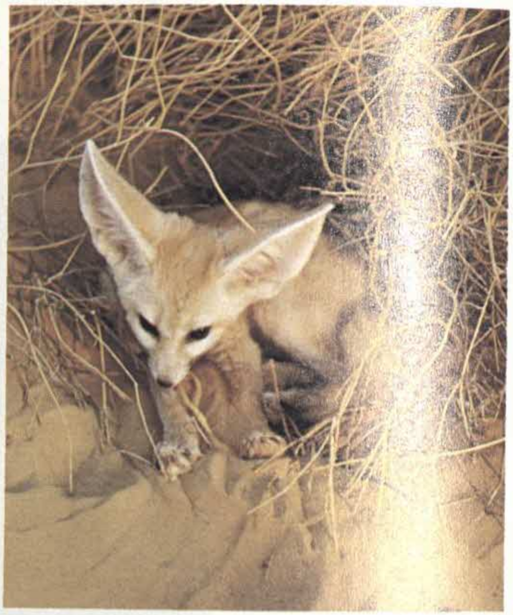
In the breeding season, the dogs generally take over aardvark dens, which they clean and enlarge. The gestation period is about two months. There are from two to six pups in a litter. As in the case of the dholes, young Cape hunting dogs are fed regurgitated food when weaned, and take part in the hunt at an unusually early age.

FOXES

The fox has long had a reputation for cunning and boldness. It is skillful in eluding its enemies and in tracking down its prey. It has an unusually varied diet. Among its victims are hares, rabbits, pheasants, partridges, rats, mice, moles, and lambs. It sometimes varies the diet with frogs, beetles, worms, shellfish, and crabs.

This animal has had a long and prosperous career. It is almost worldwide in

Leonard Lee Rue III/Bruce Coleman Inc.



Fourneau/Rapho

The bushy-tailed common red fox (left) is the best known of the foxes; the smallest is the fennec (right), which lives in the Sahara.

distribution. In fact, it is easier to list the places where it is not found than those in which it lives. There are no foxes in South America, Australia, and various islands. They are found in great numbers in the northern half of the New World, as well as in Africa, Asia, and Europe. The fox can adapt itself to a wide variety of climates. It is an important member of the fauna in the desert lands of Asia, in the frozen wastes of the arctic, and in the tropics.

The fox is raised for its fur in the United States and Canada. In the wild, the animal is often trapped, shot, or poisoned. Yet it manages to survive because of its ability to adapt itself to changing conditions. As a result, it has acquired a merited reputation for cunning. Several species of foxes are protected by law in the United States.

The best-known of all the foxes is the common red fox, which is to be found throughout the Northern Hemisphere. The red fox is about as large as a small dog. Its fur is rusty red. Its tail, which is tipped with white, is long, and bushy. It has a long nose. The red fox lives in wooded areas or in rolling country.

The gray fox is grayish in color. It has a longer body than the red fox and also a longer tail. It is to be found from the Great Lakes east to the Atlantic, in the southern United States, and in Mexico. Mainly nocturnal, it preys on rabbits and mice and, occasionally, on birds and reptiles. Sometimes it eats fruits and berries. It often climbs up a tree when pursued.

The arctic fox is particularly remarkable for the seasonal change in its coat, which is dark brown to slate in the summer and white in the winter. One variety, called the blue fox, is smoky gray or bluish drab throughout the year. The arctic fox is found in northern regions in open, treeless lands. In the summer it hunts along the coasts or in open plains. In winter it often seeks its prey out on the ice. The arctic fox sometimes follows the polar bear, eating the bear's leftovers.

Other foxes dwell in widely separated areas. Among others, there is the Tibetan sand fox with unusually short ears and tail; the small Indian fox; Rüppel's fox, found in Egypt; the African sand fox, ranging from Senegal to the Nile region; and the South African silver fox.

The smallest of the foxes is the fennec, which is found in the Sahara. The fennec is a graceful little animal about 40 centimeters long, with a tail measuring 20 centimeters. Its large, erect ears give it an alert appearance. It burrows into the sand and can dig so rapidly that it can escape most of its pursuers. It is nocturnal in its habits. It spends the day curled up in its burrow. At night it comes out for water and food.

The North American grizzly bear is now a threatened species. It used to range from the Pacific Ocean to the badlands of Dakota and north through Alaska.

Photo Researchers

BEARS, RACCOONS, AND PANDAS

The bears, which include the largest modern land-dwelling carnivores, or flesh eaters, have several smaller relatives. At first glance, the huge, lumbering grizzly bear, say, would seem to have little in common with the small, tree-dwelling raccoon. But a brief survey of the evolution of the carnivores will show conclusively that these two animals are really cousins.

EVOLUTION

Many of the earliest mammals were insect eaters. Some of these forms merely needed to increase their size and modify their teeth a bit to become true carnivores. Consequently, as the hoofed, vegetation-eating mammals evolved, there developed a group of flesh eaters to prey upon them. These carnivores had piercing canine teeth, as well as shearing teeth, or carnassials, for cutting through tough sinews and cracking bone. Since flesh is relatively simple to digest and does not need to be vigorously chewed, the grinding molar teeth were much reduced or were completely lost in the course of time. These primitive carnivores, called creodonts, were rather slow-moving and dull. However, they seem to have had no trouble in coping with their equally clumsy and dull prey.

In time the early hoofed mammals were replaced by faster and more intelligent beasts. A carnivore that hoped to make a meal of these creatures would have to be clever enough to stalk them and speedy enough to overtake them. Of the creodonts, only one line, called the miacids, developed these qualities. The earliest miacids were about as large as weasels. They were largely tree dwellers. From the miacids developed the two modern groups of land-living carnivores. The civets, hyenas, and cats comprised one group; the weasels, dogs, raccoons, and bears, the other.

The dogs retained the use of some of their grinding teeth, for they were not so restricted to a diet of flesh as were some of the other carnivores, such as the cats. The raccoons, giant pandas, and true bears—all descendants of primitive members of the dog family—departed still further from the carnivorous way of life.

The raccoons and their kin gradually abandoned the practice of using certain teeth to shear food, but they developed excellent grinding teeth. They added to their diet of frogs, shellfish, and small mammals such food as birds' eggs, fruits, nuts, and corn. The bears supplemented their meat diet with grasses, berries, fruits, seaweed (in the case of polar bears), and roots. The grinding teeth of the bears were enlarged for chewing this vegetable matter. The shearing function of the carnassial teeth was gradually lost.

BEARS

The bears, which are found on every continent, except Australia, are divided into several distinct groups. The black bears of the United States and Canada are closely related to the great brown bears and the grizzlies. The semiaquatic polar bear, too, is closely akin to these members of the family. The honey bear of India and the Malayan sun bear, however, are more distantly related, as is the spectacled bear of South America.

All bears have heavy, long fur and stubby tails. The skeleton is massive. The limbs are strong and are furnished with powerful claws for digging and for fighting. The bear has a shuffling gait. Its walk is plantigrade—that is, the sole of its foot is placed upon the ground, leaving a footprint much like that of a human.

Bears are normally slow-moving animals, yet they can break into a lumbering gallop. The black bear can run at a speed of up to 40 kilometers an hour. The big brown bear has a peculiar pacing gait. In this, first the two legs of one side are raised and brought forward together, and then the two legs of the opposite side. The brown bear will sometimes gallop for about two kilometers straight up a steep slope without stopping to rest.

Usually only young grizzly and black bears climb, but older individuals, if not prevented by excess weight or large size, occasionally take to a tree. Bears climb by literally hugging the trunk or a branch with all four limbs and hitching their way upward. They carefully back down the same way. Bears will swim across swiftly flowing rivers and navigate lakes of nearly ten kilometers in width. Polar bears are excellent divers and swimmers. They have often been sighted, in polar waters, many kilometers away from the nearest land.

Bears live from sea level to high mountain country, inhabiting swamps, forests, tundras, snow fields, and upland meadows. Black bears, grizzlies, and brown bears confine their wanderings to a fairly restricted home range. In this area they forage for food, both by day and night, seek mates during the breeding season, and spend winter in some sheltering spot.

These bears make trails through their home ranges—trails that are followed by the same individuals for years and often used by other bears that happen to be in that particular area. Bear trails along salmon streams and in heavy forests are like any game trail that leads through dense vegetation. On the tundra, big brown bears often establish trails that consist of two parallel ruts, like the ruts of a wagon trail, but, of course, much closer together. Brown bears sometimes walk their range by stepping in the same footprints they made in the past. The result is a trail formed by a series of deep pits laid out in a zigzag pattern.

Bears let their presence be known by so-called bear trees. Often such trees stand conspicuously beside a bear trail. They are marked by smooth places where a bear has rubbed itself or by jagged wounds where the bear has clawed at the bark. Strands of hair adhere to the bark and stick to the sap that oozes from the claw marks. Sometimes bears strip the bark from trees and scrape off the pulp that covers the wood, leaving tooth marks where the pulp has been removed.

Feeding signs also reveal the presence of bears. Ground-squirrel burrows that have been dug into and ant hills that have been scooped out show where a bear has fed and on what it has preyed. Overturned and smashed logs and rolled-over rocks are signs that a bear has been searching for ants and beetles. A patch of uprooted vegetation may mean a bear has dug for roots. Bee trees are ripped apart for their contents of both honey and bee brood. Since bears cover leftover portions of food with debris, the discovery of such a cache signifies that a bear is active in the vicinity.

Food is fairly hard to come by when snow covers the land. Consequently, most bears sleep through the winter. They bed down in a sheltering cavity among rocks or in a hollow under an upturned log. If need be, a den is excavated in the side of a hill. The winter's sleep is not really hibernation, for the bear sleeps less profoundly than do true hibernators, and its body temperature remains close to normal. During this period, females give birth to their tiny, undeveloped cubs. Two is the usual number, but three or four cubs are not uncommon.

There is a confusing variety in both size and coloring in the bears of North America. Consequently, naturalists differ widely in their classifications of the different species. One view holds that there are only three true species of bears in North America: the black bears, the grizzlies and brown bears, and the polar bears. According to this view, all of the other varieties are subspecies. Others describe as many as ten different species of North American bears.

POLAR BEARS

Polar bears frequent ice floes, islands, and coastal areas of the arctic regions. They are large, magnificent animals, the males measuring over two meters in length and weighing up to 500 kilograms. Females are somewhat smaller. Polar bears are all white or yellowish white, except for their black eyes, nose pads, and foot pads. The polar bear is slender with a long neck and a small, tapering head. Its streamlined shape enables the animal to knife through the water most gracefully. It uses its front legs for swimming, while the hind limbs trail behind to function as a rudder. Oil glands in the skin oil the fur effectively so that it sheds water and keeps the body dry. A fatty layer below the skin protects against the cold, and the thick fur holds little air spaces that keep heat loss from the body to a minimum. The polar bear has broad feet, the soles of which are heavily haired to prevent slipping as the animal travels over ice.

Lee Miller/Photo Researchers

Many polar bears migrate with the ice drift in a westward direction around the North Pole.

Devoted mothers. Unlike other bears, only pregnant female polar bears den up during the winter. The males and other females prowl the sea ice and open water in search of prey.

Throughout the long winter, then, the female lies beneath the snow, and there brings forth her young. She must have within her system a sufficient reserve not only to support her own life during this long period, but to provide milk to her cubs as well.

These usually number two. They are born naked, blind, and helpless, unable even to wriggle a few centimeters to their mother's side should they be disturbed. Hidden in the close confinement of their snowy lair, there is not much danger of their being lost, however.

The lair, dug by the female polar bear before she has her cubs, is a trim burrow in the ice or packed snow. One of these dens, which was found dug at the foot of an iceberg, tunneled downward through the ice for a short distance at an angle of something like forty-five degrees. Then it angled upward for a certain space and finally terminated in an oval chamber. Lairs such as this one are temporary shelters, however, for the mother and her cubs abandon them by late February or March.

The female polar bear has proven to be one of the most devoted of mammal mothers. She stands over her little cubs to shield them from fierce blasts of icy winds. She helps them cross open stretches of water between ice masses by towing them as they hang on to her body. Sometimes she carries them on her back. There are many travelers' tales telling of the heroism displayed by mother polar bears in defense of their young against human enemies. Though mortally wounded, the mother bear will stay by her cubs and protect them to the last. If they are wounded, she will lick their wounds and try to urge them away or guard them from further harm.

Skillful hunters. This bear shows great skill in stalking its prey. When it sees a seal basking on an ice floe close to the water's edge, the bear paddles in the water, carefully approaching the quarry. Only the bear's head appears above the surface, and it resembles a bit of floating ice. If the seal rears up to look about, the hunter remains motionless, drifting. Finally the bear is near enough. It quietly sinks below the surface, swims under water the remaining distance, and comes up in a thunderous thrust to knock down the prey with a heavy blow of the paw. The bear uses similar tactics to capture eider ducks and scoters that are resting on the surface of the Arctic waters. With only its eyes and nose visible, the bear swims quietly among a flock of these birds. When a bird dives in alarm, the polar bear quickly overtakes it under the water.

Sometimes the polar bear waits patiently at a hole in the ice. When a seal pokes its head up through the hole to breathe, the hunter quickly makes the kill. Water animals are not its only prey. It often tracks down caribou and the Arctic fox. It generally refrains from attacking big male walruses when they are in the water. These animals would be dangerous foes. The polar bear often feasts on the decaying remains of a beached whale, sharing the carcass with other polar bears and even with foxes.

Polar bears usually hunt alone, though the females are accompanied by their young. From May to July is the mating season, when the adult male and female travel together. Polar bears have no natural enemies. Unfortunately, many have been killed by people. Polar bears have been known to live to be thirty-four years of age.

BROWN BEARS AND GRIZZLIES

The brown bears have an extensive range over the mountainous and forested areas of the Northern Hemisphere. Consequently, there are many local races of these bears, which differ from one another in color and minor characteristics. There are brown bears in the Pyrenees, the eastern Italian Alps, the Balkan Peninsula, northern Scandinavia, and Finland. They also occur in northern and central Asia.

The Syrian bear is a light-colored brown bear of the mountains from Turkey to Iran. The isabelline bear is native to the Himalayas. A darker race lives on Hokkaido Island, Japan, and on the Kuriles and Sakhalin Island in the Sea of Okhotsk. In the northern parts of North America, Europe, and Asia, there are a number of brown bears of great size. Many of them are local subraces, each occurring in only a very small range. They may even be restricted to a single island.

The brown bears of North America inhabit the coastal regions of Alaska and adjacent islands, frequenting especially those rivers running with salmon.The famous Kadiak, or Kodiak, bears are found only on Kadiak, or Kodiak, Island off Alaska. These giant beasts may reach a length of three meters and weigh more than nearly 700 kilograms. They are the largest land-living carnivores in existence. They eat both vegetation and animal food.

Another interesting local race is the Kamchatka bear of northeastern Asia. This Asian giant lives entirely on salmon that it catches while wading in a river. It does not knock the fish out of the water with its paw, as many people believe. Actually the animal spears its prey on its claws and then leaves the river to eat the fish on land. It will never feed while in the water.

The Sitka bear is a smaller (though still very large) local race. The Yakutat and Kidder's bears on the mainland of Alaska are huge animals. All the Alaskan bears are reported to be less fierce than the grizzly, though far exceeding the latter in size.

The closely related grizzly bears live in the Rockies through British Columbia and Alaska. Grizzlies and brown bears are large animals that often cannot be easily told apart. They both have humps at their shoulders and their heads are massive, though the brown bear's head is larger. The claws of the brown bear are of moderate length and deeply curved, while those of the grizzly are long and straight. Usually the big brown bear, which may stand 150 centimeters at the shoulder, has a uniformly yellowish to dark brown coat. The grizzly has a more frosted appearance, due to the fact that the hairs, especially those on the back, are tipped with white. This bear's shoulder height does not often exceed one meter.

At one time, the grizzly bear was the scourge of North America from the badlands of Dakota to the coast of California. As time went on, large numbers of these bears were poisoned and hunted down by ranchers whose flocks they were raiding. As a result, the animal is now quite scarce. It usually reaches about two meters in length and may weight up to 640 kilograms. Although not so large as its northern cousin, this bear is far more savage. The grizzly bear is considered by many hunters to be the most dangerous of all North American wild animals. Its terrible claws are highly developed and are wielded by the grizzly with great effectiveness. Grizzlies have been known to kill full-grown bull bison with a single blow on the neck with a paw. It is said that these bears can drag away a male elk weighing 450 kilograms.

Hunting in their territory. Though brown bears and grizzlies eat many kinds of foods, this diet often varies with the season. A survey of what grizzlies eat shows that in the spring they dig up roots. In June and July they feed on reed grass and horsetails and, when opportunity arises, on rabbits, young caribou, and mountain sheep. In August and September they live on berries. Ground squirrels are eaten at any time, as are the remains of animals left by wolves.

Usually grizzlies and brown bears restrict their hunting activities to a definite territory, or home range. The home range of the Alaskan grizzly covers about 170 square kilometers. The grizzly is said to mark the boundaries of its range, as a sign to other bears, by making teeth and claw marks on trees as high as it can reach. The brown bear of the Soviet Union roams over an area of 25 to 30 square kilometers. Brown bears leave "scent signals" to indicate their territory by rubbing the back against a tree and leaving urine at its base.

Bears hear well, but they have a better nose for detecting game. Since their flesh is not particularly good, their only enemy seems to be the so-called sportsman who is out to get a trophy. These animals usually adopt a defensive attitude toward humans. A brown bear rarely attacks a man unless he blocks its path or molests a female bear that is accompanied by its cubs.

Hibernation. During the winter the brown bear hibernates, seeking the shelter of a tree or cave. It may scrape a hole beneath a fallen tree or it may enlarge a burrow begun by another animal. When it goes to rest, it has a large store of fat on which to live during the winter months. Instinct tells the animal when it has accumulated enough to last it through the winter. If food has been scarce during the preceding season, the bear may have to delay its winter sleep. During hibernation, only the bear's essential life functions remain in operation – respiration and circulation. All others are suspended.

In January or February, the female bear gives birth to one to four bear cubs. The number is generally two. The rat-sized cubs are blind at birth and weigh less than one kilogram. They first see the light of day in April or May when the mother bear emerges from her winter home. The mother transports each infant by carrying the cub with its head held in her mouth. The young develop slowly. The cubs remain with the mother for the first two years of their lives.

When the bear emerges from its hibernation in the spring, it is lean and hungry after supporting itself and perhaps several cubs on the fat of its own body during the winter. It feeds voraciously at this time on both vegetation and flesh. It may even raid cattle and sheep herds.

BLACK BEARS

The American black bear is the smallest of North American bears. It grows to a length of nearly two meters and stands almost one meter at the shoulder. Its claws are comparatively short and curved. At one time the encroachment of human civilization threatened the existence of this animal over much of its territory, but laws for its protection and the bear's own resourcefulness have ensured its survival. A forest and swamp dweller, the black bear inhabits much of Canada and Alaska, the eastern mountains from Maine to Florida, the Rockies, and the mountains of the West Coast. In the east, the bear usually wears a coat of glossy black. In the west, however, many black bears are reddish brown and are known as cinnamon bears. There is even a creamy white variety of black bear, called Kermode's bear, living on Gribbell Island, British Columbia.

An extremely powerful animal for its size, this carnivore usually hunts, day or night, for the smaller animals such as rodents, frogs and insects. It also eats berries and roots and supplements its diet with an odd assortment of foods, including pine cones, skunk cabbage, river-clam shells, briars, and wasps' nests! The nests of bees and wasps are robbed of honey and the young insects.

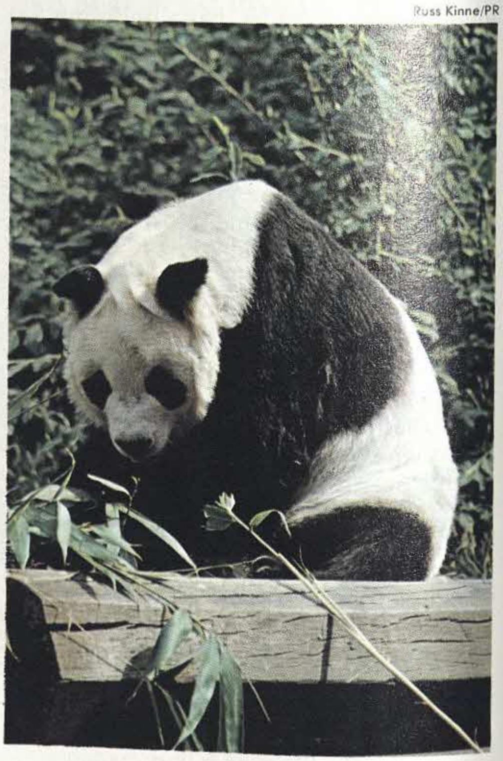
Black bears are ordinarily solitary animals living in a well-defined home territory. Trees with clawed and chewed bark indicate that a bear lives in the area. Sometimes several bears congregate at a feeding ground, such as a berry patch or garbage dump. Relations among them may be peaceable, but often fights take place.

The sexually mature males and females associate during the breeding season, which lasts approximately one month in June or July. After mating, the bears go their separate ways, the male having nothing to do with the raising of the family. Like other bears, black bears den up in rocky caves, hollow trees, or beds of dense foliage for a prolonged winter sleep. In late January or February, cubs are born—usually one cub to a female having her first offspring and two or three young to an older female.

The newborn cubs have a thin coat of fine hair and are blind and toothless. They are about 20 centimeters long and weigh less than one-quarter kilogram. In March or April, when the cubs weigh about two kilograms, they leave the den with their moth-

The giant panda is one of the world's most popular creatures. Because of its remote habitat and limited diet, however, it may be in danger of dying out.

Russ Kinne/PR



er. She continues to nurse them for some time, but they also eat other foods. The cubs box and wrestle each other and engage in games of hide-and-seek. When in danger, they scurry up a tree if they cannot reach their mother. The young remain with the mother through the following winter. In the wilds, black bears probably live from twelve to fifteen years. The females are sexually mature at three years. They mate about once every two years.

The *Himalayan black bear* is the most widespread of three Asian black bears which range from the eastern portion of Iran through Afghanistan, Tibet, and Thailand into China and Manchuria. It is also found on the islands of Hainan and Taiwan. Somewhat smaller than the American black bear, it is further distinguished by a light-colored, inverted crescent or Y-shaped patch on its chest. The hair on the neck is long, giving the animal a sort of ruff. The bear is a forest creature, living on grain, honey, roots, fruits, and grasses.

The *Malayan sun bear*, or bruang, is a smaller species restricted to the Malay peninsula and the islands east to Borneo. It has a crescent of white or orange on its chest similar to that of the Himalayan black bear. The animal is an excellent tree-climber. It has flexible lips, which it uses in feeding on insects and honey.

The *sloth bear* of India is a more specialized insectivorous bear. This creature differs from the rest of the bear family in having two fewer teeth than the normal quota, a long snout, and a baggy, hanging lower lip. The shaggy beast lives on fruits, flowers, honey, and insects. It is particularly fond of termites, which are its natural prey. Its immensely powerful claws enable it to tear open the hills of these insects. The sloth bear's extraordinary powers of suction then come into play, as it draws ants from deep within the nest by a violent intake of breath.

The *spectacled bear* of the Andes, in South America, is a close relative of the sun bear. It is a small, black species, found in the mountains from Colombia to Chile. The name is derived from the whitish, spectaclelike rings about the animal's eyes. It is the only known bear in South America. The one other bear found in the Southern Hemisphere is the Malayan sun bear in Sumatra and Borneo.

PANDAS

When the *giant panda* was first discovered in 1869 by the French missionary Armand David, it was believed to be a bear with abnormal coloring, because it had so many bearlike characteristics. It was classified with the bears for a long time, but as zoologists came to know more about the animal, they realized that it may be related to the raccoon. In fact, the giant panda has no very close genetic relatives.

The giant panda reaches a length of about two meters and weighs over 90 kilograms. Like the members of the bear family, it has plantigrade feet, strong claws, and a short, stumpy tail. However, it has two fewer teeth than the ordinary bear. In coloring, the panda is white or cream-colored, except for areas of black around its eyes, ears, legs, and shoulders.

The panda lives in three remote provinces of China, at elevations of 1,800 to 4,000 meters. Because its feeding grounds are so limited, however, and because the bamboo shoots on which it feeds almost exclusively appear to be dying out, the giant panda may also be in danger of extinction. About a quarter of the world panda population have already perished. Scientists are watching to see if the panda will be able to adapt its diet to include other plants or even small animals.

There are about 35 pandas in zoos around the world, but efforts to breed them in captivity have usually failed.

The *true panda*, or *lesser panda*, as it is more commonly known, is a bushy-tailed animal about the size of a large cat. Its back and head may be brown, red, or chestnut. Reddish-brown is the color of its underside, legs, feet, and ears. The ears, cheeks, and chin are trimmed with white. The face is white below the eyes and there are white spots above them. On the ground the true panda is slow-moving, but it is an excellent tree-climber. Like the giant panda, it lives mainly on bamboo shoots, but in captivity it will eat bread and milk, eggs, and small birds. It hisses like a cat, growls like a bear, and laps, at times, like a dog. Generally, however, it plunges its muzzle into water and drinks by suction, after the manner of a bear. The true panda can partially retract its claws, like a cat. The animal is a native of Asia, but formerly ranged over Europe to the British Isles, at a time when this region had a subtropical climate and was abundantly forested.

RACCOONS

The German name for the raccoon is *Waschbaer*, which means "washing bear." It is derived from the fact that this little bearlike mammal appears to wash its food before eating it. The raccoon is closely related to the bear. For one thing, like the bear, it has plantigrade feet. Raccoons have the same number of teeth as sloth bears and pandas. Internally, too, there are anatomical similarities among these animals.

The raccoon is particularly noted, perhaps, for the way it seems to meticulously wash its food before eating. Although not an aquatic animal, the raccoon usually lives near water. It uses its nimble paws as dexterously as a monkey to probe a stream bed for snails and other food, with what looks like a scrubbing motion. When the raccoon finds its dinner, however, it eats it quickly without taking time to clean or even rinse it.

The common raccoon of the United States and Canada is about as big as a domestic cat, but the length of its legs and the bushiness of its coat make it appear larger. The back is highest over the hindquarters. The head is triangular. Patches of black over the eyes give the face a "banditlike" appearance.

The raccoon has a varied diet. It is fond of frogs, crayfish, oysters, and other shellfish. It also eats birds' eggs, poultry, mice, nuts, fruits, and corn. The raccoon's appetite for ears of young corn arouses the particular animosity of farmers.

Raccoon attacks on chicken farms and corn fields are particularly bothersome to the farmer because these animals are so clever and so destructive. It is particularly difficult for the farmer to catch them, because they seek their food only at night. In the daytime the raccoon sleeps, generally in the hollow of a tree. When it attacks chickens, the animal usually kills far more birds than it can possibly eat. Corn-field raids are equally destructive, because the raccoon not only greedily devours many ears of corn but also knocks down a number of stalks.

Raccoons find most of their food on the ground, but they generally live in hollows in trees because it is so much safer for them. They hibernate in these places of refuge in the colder parts of their range; it is in the trees that their young are born. The raccoon is quite wary, although it has relatively few enemies other than man. It is adept in climbing trees and often uses this way of escape when danger threatens. Despite hunting, it is increasing in numbers in some areas.

A common raccoon with bushy coat and banditlike black eye patches prepares to feed on a fish it has caught.

Leonard Lee Rue III, Audubon/PR

American Museum of Natural History

The mink is a large version of the true weasel. Minks live on the ground, making dens in hollow stumps, crevices, or burrows.

THE WEASEL FAMILY

The members of the weasel family include not only weasels but also martens, wolverines, minks, skunks, and other animals. For the most part they are slim and lithe carnivores, noted for their courage and their strength. Most of these animals dwell in the north temperate zone, but representatives of the group are sometimes found in other regions.

The weasels are believed to have evolved from small, tree-dwelling carnivores called miacids, which lived something like 40,000,000 years ago. Among the descendants of the miacids was a weasel about the size of a black bear. that lived in North America about 25,000,000 years ago. Today the members of the weasel family range in size from the tiny weasels proper through the medium-sized skunks and martens to the wolverines, which may weigh as much as 15 kilograms.

Modern members of the weasel family have evolved but little in some respects from their earliest known ancestors, the miacids. They usually have long, lithe bodies and stocky legs. They have specialized teeth for shearing tough meat fibers. Some still dwell in trees. Others do not. The badger, for example, has become a burrowing animal. The otter is well adapted for life in or near the water. Many weasels have scent glands: those of the skunk are particularly well developed. Certain members of the group have coats of thick, dense fur.

MARTENS

Martens are generally tree-dwelling members of the weasel family. Among the most striking members of the weasel family is the American marten, often called the American sable or pine marten. This handsome animal, which is an expert climber, is about 60 centimeters long. It is colored a rich, light brown above. Its underparts are darker brown, as are its legs and bushy tail. Its wide throat patch is whitish or buff. Martens avoid people. They are found in the denser forests of Canada from the Atlantic to the Pacific, in some parts of New England, and in some regions of western North America.

Martens hunt squirrels in the treetops. On the ground they track down rats, rabbits, and grouse. They are active during the winter, traveling easily over the snow as they hunt for mice and shrews. They often supplement their meat diet with insects, honey, berries, fruits, and nuts. The female marten builds a grass-lined nest in a tree hollow or burrow, in which from one to five young are born in April. The chief enemies of the marten, besides man, are the horned owl, the lynx, and the fisher, also a member of the marten group.

FISHERS

The fisher, or pekan, is a large, powerful animal that looks like a bulky, long-nosed cat. It measures about one meter in length. Its long and soft fur is much darker than that of the American marten. The fisher dwells in the northern part of the United States and in Canada. It is sometimes found in the neighborhood of swamps and other bodies of water, where it preys upon fish, frogs, muskrats, and beaver. It also hunts at night for rabbits, squirrels, and other small mammals. The fisher is one of the few animals that attacks the porcupine. It turns this rodent over on its back and pounces upon its underside, which is not protected by the formidable quills. The trapper regards the fisher as one of his chief enemies in the wilds, since it steals the bait in his traps and eats any animals that are caught in them.

WOLVERINES, TAYRAS, AND GRISONS

The wolverine is the largest animal in the weasel family. It is also known as the glutton in Europe and as the carcajou in Canada. As an adult, it is as large as a small bear. The wolverine lives in forests in northern Europe, Asia, Canada, the United States, and possibly Greenland.

In the winter the wolverine chases elk, deer, martens, foxes, and lynx. It cannot chase prey on snowless ground, however, and in summer feeds on carrion, birds' eggs, lemmings, and berries.

Trappers dislike the wolverine because the animal raids traps and takes all the edible material it can find. It also takes fur pelts. The wolverine itself does not have a valuable pelt, and it is rather difficult to trap.

Two smaller but very troublesome and savage members of the weasel family are the tayra and the grison, both found exclusively in Central and South America. The tayra matches the otter in size. The grison has more the proportions of the marten. Both frequent hollow trees, clefts in rocks, and the deserted burrows of other animals. Both prey upon various small mammals and birds. Eggs also play an important part in their diets.

TRUE WEASELS

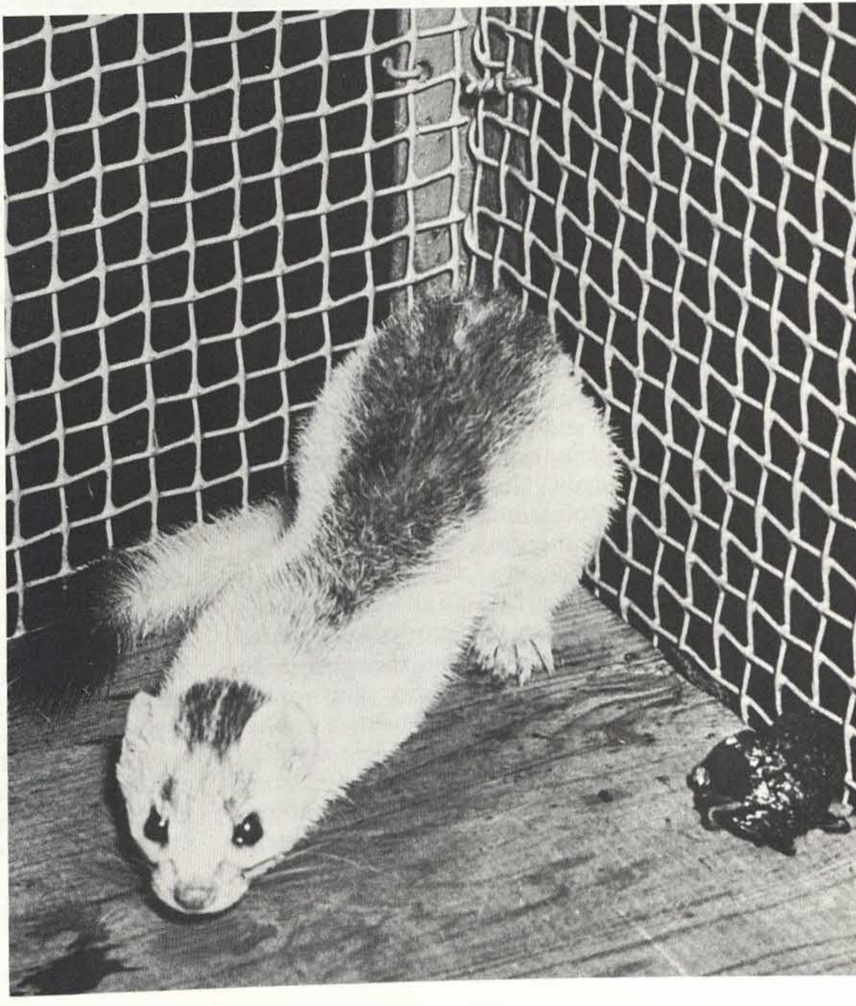
The true weasels are distinguished from the martens by their small size, slimness of body, preference for the ground—although all are good climbers—their close fur, comparatively short tails, and change of coat in winter. Several species inhabit the Old World, of which the most familiar is the *stoat,* or true *ermine weasel.* Several others are found in North America, and one in South America, ranging south along the Andes. The best-known North American species are the common, or short-tailed, weasel, the northern long-tailed weasel, the little "mouse-hunter" of the northern plains, and the bridled weasels of the Pacific Coast, marked with a black band across the face. The Arctic coast has another species very like the stoat. But wherever the weasel is encountered, he is found to be "a keen, agile, indomitable hunter."

Weasels are graceful and quick, and are very efficient hunters. They stalk their prey by sound, sight, and scent, and will often follow their prey into burrows and kill them there.

Weasels kill more than they can eat. They instinctively chase prey even when they are not hungry, and they seldom give up until the prey is caught. Weasels have very sharp teeth that they use to kill their prey quickly. They typically bite prey at the base of the skull, the sharp teeth penetrating the skull and passing into the brain, causing rapid death.

Weasels are very fierce when they are confronted by some other animal. But they can be literally "scared to death" by falling into a trap.

The fur of all the true weasels – in summer, light or dark brown above and white, sulfur yellow, or orange, according to species, underneath – becomes white in winter wherever the climate is such that snow remains continuously from late November to April. South of the line of permanent winter snow the weasels keep their brown color all the year round, but along this climatic borderland they may become partially white, as in the case of the ermine. The weasels are of great service in destroying vermin in the fields and in hunting rats and mice about barns and storehouses.



New York Zoological Society

All true weasels change their fur color in winter. Here an eastern weasel shows partial winter white fur.

The South American tayra is a savage member of the weasel family.

New York Zoological Society

MINKS

Minks are found in northern Europe and over all the North American continent. The mink is larger, stouter, and more robust than the weasel, and its fur is everywhere thicker and darker brown in color, except for the white patch of variable extent on the chin. It lives on the ground, making its den in holes under or inside old stumps, in crevices among loose rocks, or in burrows usually opening in the bank of a stream or lake. It hunts its food mainly along stream and lake shores where it preys upon frogs, fish (especially eels), and other aquatic animals. Though trapped by amateurs and professionals alike, it holds its own in even the most thickly settled regions.

Mink farms are now a successful enterprise throughout the northern United States and Canada. The minks are carefully raised and tended. Most mink skins for fur coats now come from these farms.

POLECATS

The polecats are related to martens, the only major difference between them being the foul-smelling fluid polecats emit when faced with an enemy. The name "pole," or "pol," as it was originally spelled may be a corruption of the French *poule*, a hen, in reference to the animal's great weakness for poultry. Or it may come from the old English word *foumart*, or "foul marten," referring to its odor.

Various species of polecats are common in many parts of Europe and Asia. Though they vary in size and coloration, their habits are similar and their odor is equally abominable. It represents a truly remarkable feat for man to have bred the domesticated type of polecat that we call the ferret so that the offensive odor has largely disappeared.

The *ferret* differs from the polecat in the color of its fur, which is generally yellowish white. Its eyes are pinky red. The animal is about 35 centimeters long, not including the tail. It is exceedingly prolific: each year the female brings forth two broods, each numbering from six to nine young. The ferret is often used to kill mice and rats. It also serves to drive rabbits from their burrows. The rabbits are shot by hunters as they emerge. According to the an-

New York Zoological Society

The skunk is well known for its offensive odor. Skunks eat small animals and are frequent raiders of chicken coops.

cient Roman naturalist Pliny, his countrymen also used ferrets for rabbit hunting.

Like all members of the weasel family, ferrets are instinctive killers. They must be muzzled before being turned into a rabbit's burrow. Otherwise they would kill and eat the rabbit. They are not muzzled, however, when they are used to kill rats, since these rodents are fierce fighters when cornered.

RATELS

The ratel is found in India and Africa. Ratels are badgerlike in build, with rudimentary ears. They have powerful claws, with which they can dig themselves into the ground with great rapidity in time of danger. They are generally black in color, with a whitish crown and a somewhat grizzled back. The ratel is fond of honey, and for that reason it is sometimes called the *honey badger*. It also eats rats, frogs, birds, and insects, particularly termites. It is very fond of poultry and occasionally raids chicken coops.

SKUNKS

Skunks are black in color, with white longitudinal stripes or white spots. They are found in many areas of the United States and Canada. They commonly avoid deep forests and deserts, preferring slightly wooded or open country. They eat insects, mice, frogs, and snakes, but sometimes they raid poultry yards.

Skunks hibernate during the winter. In the spring, the female has a litter of from six to ten young.

Specialization reaches a high point in the American skunk, whose defense mechanism is about as effective as can be found in the animal kingdom. The skunk is equipped with scent glands from which it can, at will, discharge a most nauseating fluid. This fluid, which is clear yellow in color, is dispensed in a fine spray that can carry as far as three meters at the time of discharge. Air currents can distribute it even farther. The spray is strongly acidic. If it gets into the eyes it may bring about temporary blindness. The sickening odor of the fluid is so penetrating that it generally puts to rout any attacker.

The skunk uses its defensive spray only when it is sufficiently provoked or actually attacked. It gives due warning of its intent by turning its back to its tormentor and raising aloft its long, bushy tail. The animal relies so thoroughly upon its defensive weapon that when it is attacked, it almost never tries to escape or to defend itself with its sharp teeth.

BADGERS

The badger is another interesting member of the weasel family. The American badger, distributed over the western and central parts of North America, is a clumsy, heavy-bodied animal, with a much flattened body and a short and bushy tail. It is silvery gray and black above and yellowish white below. The animal is a powerful digger. It is equipped with strong front legs and long claws. It digs burrows in the ground for its own use. It also digs out the burrows of other animals, such as gophers, prairie dogs, and the like. The badger travels from one burrow to another in its nightly hunting and devours any occupants. It also preys on small mammals that attack the crops. The fur of this animal is of considerable value. Its bristly hairs are widely used for artists' brushes and shaving brushes.

The European badger is quite similar in appearance to the American variety, but differs somewhat in certain details; for one thing, the head is much more slender. Its general habits and food are much like those of the American badger. Badgers are also found in Asia and Africa.

The American badger is a short, stocky animal. It preys on many rodent pests.

New York Zoological Society

OTTERS

Next we come to the otter, which is perfectly at home in the water. It has the webbed feet, short and thick fur, and small ears that are characteristic of aquatic mammals. Its legs are short. Its rudderlike tail is fairly long. The otter is a handsome animal, with dark brown fur. An excellent swimmer and diver, it feeds almost entirely on fish. However, when fish are scarce it will hunt crayfish, frogs, and muskrats. It is found in Europe, Asia, southern Africa, and the Americas.

The otter rests for the greater part of the day in its den, near the stream in which it fishes. It comes out at night to feed. This den is usually an excavation in the bank or in a log lying close to the stream. If the den is in a bank, the entrance is often to be found below the water line.

The otter is a playful animal. It loves to slide down river banks or snowy hummocks. It can be tamed quite easily. It can be taught to follow its master like a dog and to enter and leave the water at a word of command. It can even be trained to catch and bring in fish. It is first taught to retrieve things on land and afterward to fetch and carry a dummy fish thrown into a river. Then comes the catching of a real fish cast into the stream.

SEA OTTERS

The true sea otter of the North Pacific is quite a different kind of animal. It is more seal-like than the otter and is particularly well adapted for a marine habitat. Its natural habitat is restricted to a few islands off the coast of California, Alaska, the Soviet Union, and Japan.

The sea otter is a little more than one meter in length. It has a flat and broad head, very short ears, a flexible body, short limbs, and a short tail. Its front feet are small. The hind feet are webbed to form flippers, sug-

New York Zoological Society

The American otter is a very playful and affectionate animal. Otters are found on all the continents except Australia.

gesting somewhat those of the seal. The molar teeth are provided with grinding surfaces for crushing the shells of various kinds of shellfish. In addition to shellfish, the sea otter feeds upon salt-water fish of various kinds, cuttlefish, and sea urchins.

The sea otter has a very valuable pelt, and it has been widely hunted. Because of this, the animal was faced with the danger of extinction. However, the U.S. and Soviet governments responded to the alarming drop in population and enacted laws to protect the animal from hunters. Today, the number of sea otters has greatly increased, and it is not likely that the species will disappear.

Sea otters do not do well in captivity. When caught as babies they refuse food. Adults will accept food, but they rarely breed in captivity.

In a typical position for feeding, a sea otter floats on its back in the water as it devours a crab.

Alexander Lowry/PR

CIVETS, MONGOOSES, AND HYENAS

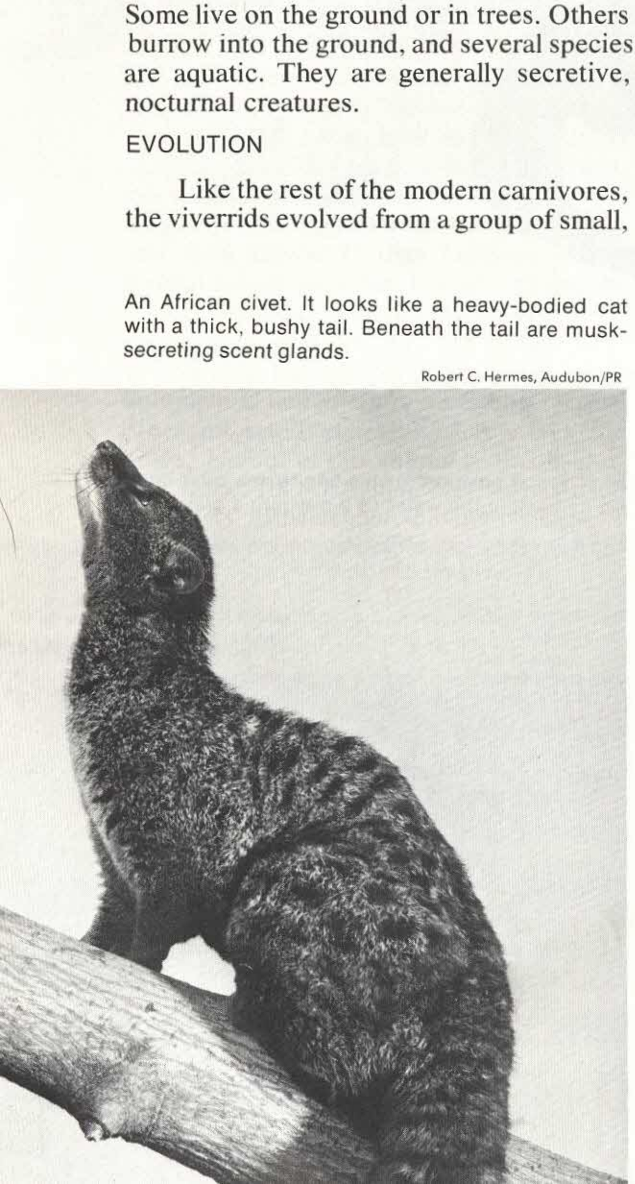
In Africa and tropical Asia we find a family of carnivores, or flesh eaters—the Viverridae, or viverrids, which range from small to moderate size. These animals, whose name comes from the Latin word *viverra*, meaning "ferret," include the civets, mongooses, and their allies. They lead much the same kind of life in the Old World tropics as do the weasels and their kin in the more temperate regions of the world. Some live on the ground or in trees. Others burrow into the ground, and several species are aquatic. They are generally secretive, nocturnal creatures.

EVOLUTION

Like the rest of the modern carnivores, the viverrids evolved from a group of small, weasellike, forest-dwelling flesh eaters known as miacids. At the end of the Eocene epoch, about 40,000,000 years ago, the miacid stock branched out, giving rise to weasels and dogs, on the one hand, and to the viverrids, on the other. The cats, in turn, evolved from some of the early viverrids.

An African civet. It looks like a heavy-bodied cat with a thick, bushy tail. Beneath the tail are musk-secreting scent glands.

Robert C. Hermes, Audubon/PR



The viverrids are comparatively primitive and unspecialized animals. Some of them have changed little, apparently, from their miacid ancestors. The skull is long and narrow, and the face suggests that of a fox. The teeth are typical of carnivores. The carnassial teeth are extremely sharp and form efficient shearing blades.

THE CIVET FAMILY

There are over 100 species of viverrids, divided into six main groups: the civets, genets, and linsangs; the palm civets; the hemigales; the galidines; the mongooses; the fossa.

CIVETS, GENETS, AND LINSANGS

The animals of the first group—the true civets, genets, and linsangs—belong to the subfamily Viverrinae. They are more closely related to the cats than are any of the other viverrids. Their bodies are more streamlined, however, than those of cats, and their heads are foxlike. Though some of them climb trees, their feet are better adapted for walking and running on the ground. The curved claws can be more or less retracted, or drawn back, into sheaths, much as in the case of cats. The Viverrinae inhabit Africa, India, and Malaysia.

The African civet (genus *Civettictis*) and the Oriental civet *(Viverra)* resemble each other closely. They are heavy-bodied creatures about as large as domestic cats. They are exceptionally narrow and stand high off the ground. The hind legs are longer than those in front, causing the body to slope downward from the rear. The fur shows dark streaks and blotches. Dark hair can be erected along the back to form a crest. The bushy tail of these civets is shorter, comparatively speaking, than that of other viverrids. Beneath the base of the tail are scent glands that secrete a thick, dark yellow substance called *civet*, or *musk*. It is composed of a complex mixture of ammonia, fats, and volatile oils, and has a strong, pungent odor. To extract musk for commercial use, civets are kept in captivity and "milked" every two or three weeks. The musk is used as a fixative in the manufacture of perfume and medicines.

The rasse *(Viverricula)* is a smaller Oriental civet, lacking a crest on the back but possessing well-developed musk glands. It is an expert tree climber. The water civet *(Osbornictis)* is an otter-shaped animal with beautiful reddish brown fur, dark and light markings on the face, and a bushy tail. Its feet are webbed and the soles are naked. It can travel easily on mud flats. The water civet is a fish eater.

Genets. Another beautiful civetlike animal is the genet *(Genetta)* of Africa, southern Europe, and southwestern Asia. Its yellow or grayish fur is darkly spotted, and dark bands ring the very long, tapering tail. A crest of dark stiff hairs can be elevated along the back. The lithe and graceful animal haunts open forests or rain forests, where it seeks its prey. It is equally proficient as a hunter on the ground or in the trees. When pursuing prey, a genet elongates and flattens its body and glides along the ground or on a branch in an almost snakelike fashion.

Linsangs. Like the genet, the Asiatic linsang (*Prionodon*) stalks its prey by crawling with its belly to the ground. Since it is so slender, it is often mistaken for a heavy-bodied poisonous serpent. The linsang looks like a small genet. Its tail is exceedingly long. Its coat is light in color and marked with bands or spots. The animal does not possess musk glands. The African linsang (*Poiana*) is a spotted, genetlike carnivore of western Africa.

PALM CIVETS

The animals of the next viverrid group—the palm civets (subfamily Paradoxurinae)—are less agile and catlike than the true civets. Their feet are better adapted for climbing, and they are almost completely arboreal. They possess musk glands.

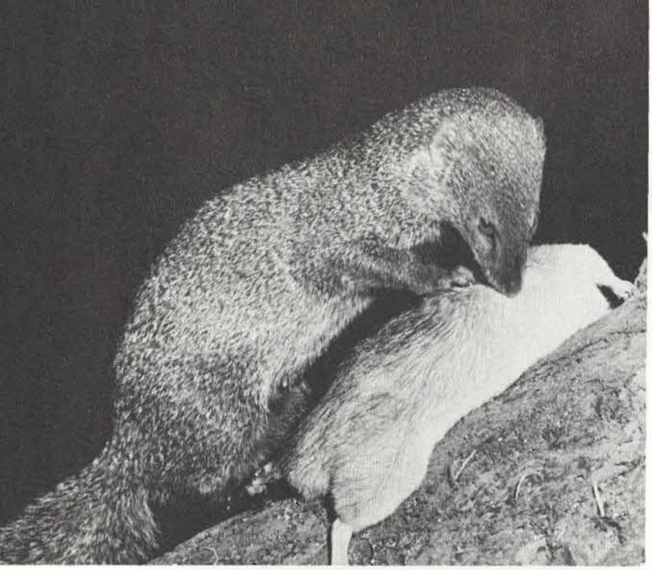
Arthur Ambler, Audubon/PR

A rusty-spotted genet of Africa. Genets are closely related to civets but generally have more pointed faces and prominent ears.

Binturong. Among the most striking of the palm civets is the binturong, or bear cat (*Arctictis*), which dwells in Indonesia and southeastern Asia. The binturong has a prehensile, or grasping, tail that it uses as an extra hand as it moves slowly and deliberately through the dense forest canopy. It has a long, shaggy coat of coarse, black hairs. Long tufts of hair project from the top of its short ears. Its teeth are comparatively small.

HEMIGALES

The viverrids known as hemigales (subfamily Hemigalinae) include several little-known carnivores of Malaysia and Madagascar. The banded palm civet, or hemigale (*Hemigalus*), resembles the lin-



Lewis W. Walker, Audubon/PR

Mongooses are small, agile hunters. They feed on small birds and reptiles, mice and rats, and at times on snakes.

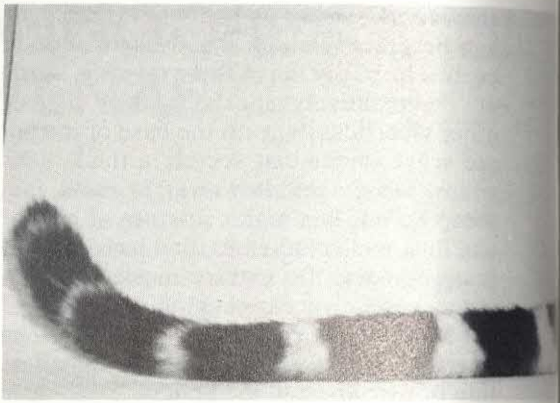
sang. It is prettily marked with black bands across the back. Its face and neck are reddish. It has climbing-type feet. Its scent glands are not well-developed. The Indo-Chinese civet *(Chrotogale)*, which has an elongated muzzle and small teeth, and the *Diplogale* of Borneo are rare close relatives. The otter civet *(Cynogale)* is equally at home in the trees and water. Like an otter, it has broad, webbed hind feet, a swollen upper lip, a broad muzzle, a flat head, small ears, a short cylindrical tail, and thick, dense, soft fur. Hemigales of Madagascar include the Malagasy civet *(Fossa)*, which looks like a genet, and the falanouc (*Eupleres)*, which is a long-snouted animal with a short tail like a bottle brush.

GALIDINES

The Galidines, or Malagasy mongooses (subfamily Galidiinae), seem to be a link between the civets and true mongooses. They are small, graceful animals, some no bigger than rats. Galidines are common in the Madagascan forests of giant ferns, where the ground is densely covered with vegetation. One type (*Galidia*) is bushy tailed and scampers during the day through the trees like a squirrel.

TRUE MONGOOSES

Great numbers of true mongooses (subfamily Herpestinae) live in Africa,

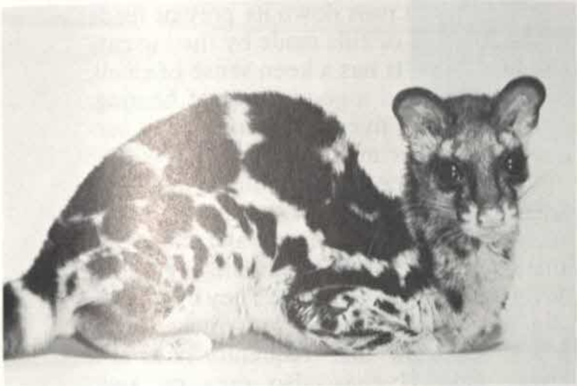


southern Asia, and Indonesia. These animals lack scent glands. In general, they are slender and long-bodied creatures, with pointed snouts, very short, rounded ears, and fairly long, bushy tails. Some are weasellike, and short-legged. Others are like dogs, standing high off the ground on rather long legs. The fur is long and coarse, and is grizzled or striped. Mongooses can climb trees but rarely do so. Their long, slightly curved claws, which are not retractile, are more or less suited for digging. Mongooses are small and active carnivores, moving about by day much more than do the civets. They are easily tamed, if caught young, and are often kept to catch mice and rats.

Common mongooses *(Herpestes)* inhabit Spain, Africa, ad Asia. Several different kinds of mongooses live in Africa. Among these are the meerkat *(Suricata)*, a plains-dwelling animal that often sits up on its hind legs like a ground squirrel; the dwarf mongoose *(Helogale)*, only about 25 centimeters long from nose to rump; the marsh mongoose *(Atilax)*, which dives and swims expertly; the cusimanse *(Crossarchus)*, which spends much time underground in burrows; and several doglike forest-living species.

THE FOSSA

The fossa *(Cryptoprocta)*, belonging to the last of the viverrid groups, is the largest carnivore of Madagascar. It is the sole representative of its subfamily, the Cryptoproctinae. The animal may be a link between cats and civets, or it may have



Howard Earl Uible/PR

The linsang. With its extremely long tail and habit of flattening its body to the ground to stalk prey, the linsang is often mistaken for a heavy-bodied snake.

evolved from common ancestors of the cats, true civets, and mongooses. The teeth are catlike. The needle-sharp claws are strongly curved and retractile. About twice the size of a house cat, the fossa has somewhat the same shape as the genet. The short fur is reddish or grayish brown. The animal walks flat on the soles of its feet, unlike a cat, which walks on its toes. The fossa climbs trees readily and sometimes seeks its prey there. It also hunts on the ground.

ALL ARE NIGHTTIME HUNTERS

The viverrids are active and alert nighttime hunters. They carefully and silently stalk their prey and then pounce upon it swiftly. Small animals of all kinds are game to the viverrids: birds, lizards, snakes, and insects, as well as rats, mice, and other small mammals. Birds' eggs are also eaten. With the exception of the fossa, linsangs, and Malagasy civet, which are almost exclusively meat eaters, the viverrids supplement their flesh diet with a considerable quantity of vegetable matter, including berries and other fruits and also roots.

Like most mammals, viverrids confine their prowlings to a home range, which they do not abandon unless shortage of food forces them to hunt elsewhere.

The civet smears tree trunks, rocks, and the ground with musk and also leaves heaps of excrement at definite places, thus indicating the location of its home range to other members of the species. Musk plays a part in bringing together the male and female. It is also used as a means of defense, for the civet can discharge the secretion into the face of an attacker.

During the daytime, viverrids seclude themselves in some protected spot. A hideaway or den may be a hollow tree, an abandoned burrow made by some other animal, or a crevice among rocks.

Most viverrids are solitary, living alone except when male and female pair for breeding. Some mongooses, however, show a social tendency. Groups may hunt together, and some mongoose families may be found living together in a network of burrows.

Little is known about viverrid reproduction. The Indian civet seems to breed in May or June, and three or four young are born. Two young are produced by the Asiatic linsang, which breeds in February and August. The rasse has four or five young; the masked palm civet and the Indian mongoose, three or four. The genet, which bears from one to three young, has no fixed breeding season.

The spotted hyena feeds on the remains of kills made by other animals or makes its own kill. Here a large male defends his meal against jackals.

Mark Boulton, Audubon/PR

HYENAS AND AARDWOLVES

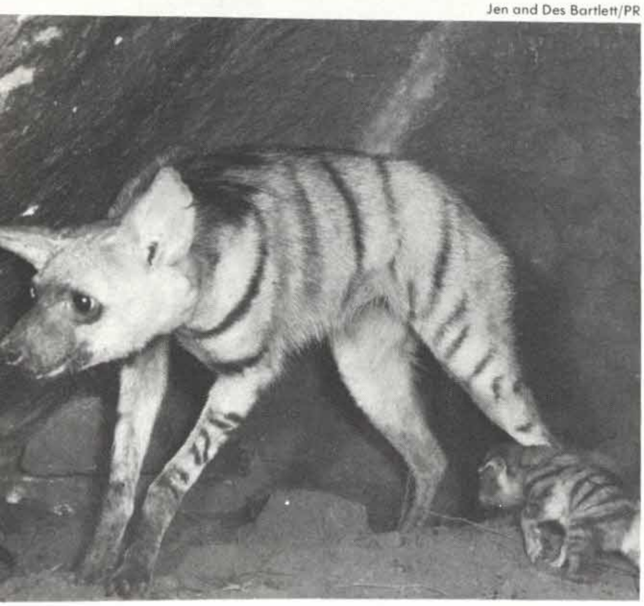
During the Miocene epoch, about 20,000,000 years ago, a line leading to the hyenas evolved from the central civet stock. The hyenas, family Hyaenidae, became fairly large and powerful scavengers resembling ungainly dogs. The skull of the hyena is heavy. The teeth and jaws are large, and the jaw muscles are exceedingly strong. The animal stands high on long, stout legs. The front legs are longer than the hind ones, causing the back to slope downward from the neck and shoulders to the rump. The claws are blunt.

True hyenas. The hyenas proper (subfamily Hyaeninae) include the striped hyena *(Hyaena)*, the brown hyena *(H. brunnea)*, and the spotted hyena *(Crocuta)*. Striped hyenas range from India through southwest Asia to north and east Africa. They are dirty-gray with black stripes on the flanks and legs, a mane on the neck and along the back, and a short and bushy tail.

The spotted hyena is somewhat larger than the others, standing a little less than one meter at the shoulder. It is yellowish buff with dark blotches, has shorter, more rounded ears than other hyenas, and lacks a mane. A common African carnivore, the spotted hyena is found over much of the continent south of the Sahara.

An aardwolf in its den with its young. Aardwolves spend most the day in a natural cavity, leaving at night to hunt.

Jen and Des Bartlett/PR



The hyena runs down its prey or feeds on the remains of kills made by the big cats and wild dogs. It has a keen sense of smell, acute vision, and a good sense of hearing. Cries of several hyenas fighting over a carcass will attract many more.

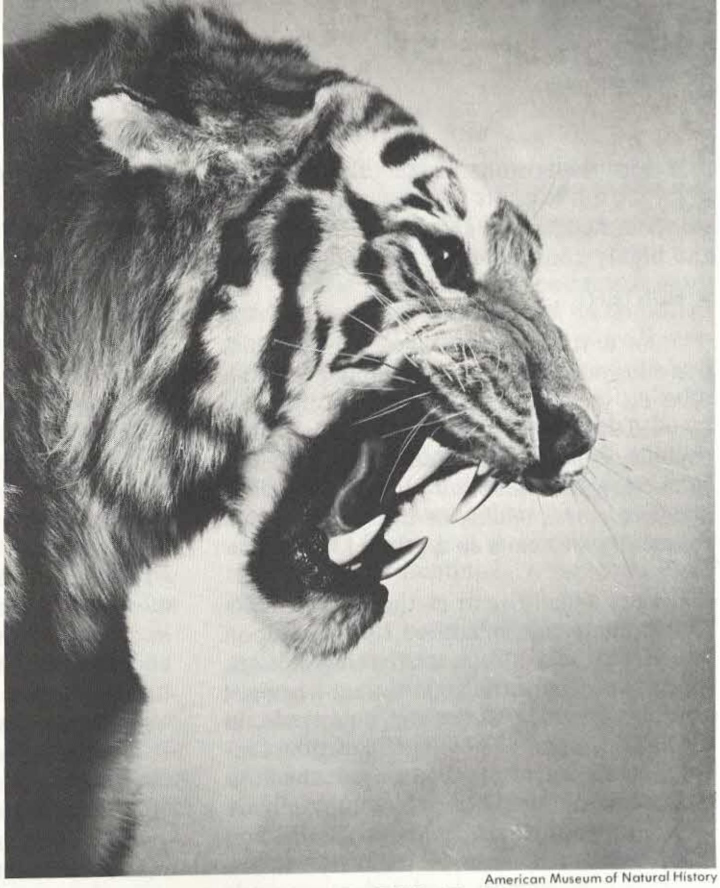
Spotted hyenas usually make their own kills. They bring down stronger animals, such as young rhinoceroses and the larger antelopes. Several will combine in running down an antelope or zebra. They utter cries like human laughter – a low-pitched hysterical chuckling that frequently rises to a higher key. Hyenas also prey on sick, young, or aged animals. Striped and brown hyenas are primarily scavengers.

Hyenas are more or less nocturnal, spending the day in natural cavities among rocks or in abandoned burrows. Where such dens are not available, the animals dig their own. Usually the spotted hyena does not have any one home range but temporarily confines its activities to an area where zebra and antelope graze.

The spotted hyena has no fixed breeding season. After a gestation period of 110 days, one or two young are born. After the pups are weaned, they are said to be fed on regurgitated food that has been brought up from the parent's stomach. The gestation period of the striped hyena is about ninety days, and usually four young are born.

Aardwolves. The aardwolves makes up the subfamily Protelinae of the hyena family. The aardwolf is somewhat similar to the striped hyena but is smaller and more slender. The aardwolf has weak jaws; except for the large canine teeth, there are only small pegs for teeth. Its fur is striped across the back; a mane runs down the center of the back; and the tail is bushy. Aardwolves live in brush, plains, and rocky country of eastern and southern Africa.

Like the hyena, the aardwolf is more or less nocturnal. It spends the day in some natural cavity. Often two or three females, each with her two to four young, will occupy the same den. At night, half a dozen or so aardwolves may travel together in search of food. Aardwolves feed exclusively on termites and other insects, on newly born animals, and on rotten meat.



The head of the Siberian tiger is characteristic of the cat family. The tiger's teeth are formidable and well adapted for eating meat.

American Museum of Natural History

THE CAT FAMILY

The cats—lions, leopards, jaguars, pumas, lynxes, cheetahs, domestic cats, and others—are carnivores, or flesh eaters. They cleverly stalk and ambush their prey. Cats must be alert and tensed to make a kill. They must also be quiet so as not to frighten off an intended victim. Sometimes cats pursue game they neither see nor smell, relying on tracks or other signs.

GENERAL BODY PLAN

The long, lithe, graceful body of a cat is well adapted to hunting. Much of the weight is supported by the forelegs. Strong back and hind-leg muscles enable the animals to spring on prey. But cats are not as sturdy runners as dogs. Instead they dash rapidly for short distances and then jump on their prey.

Cats run or walk on their toes. There are five toes on each front paw and four on each hind paw. They are armed with long, sharp, curved claws, which are retracted, or drawn in, when not in use.

A cat's head is large, the face relatively short and rounded. A bony crest at the top of the skull anchors the strong lower-jaw muscles. The animal's teeth are well adapted to its diet. The front teeth, or incisors, bite off flesh. The fangs or canines, are like daggers for biting deeply. The upper and lower side teeth, carnassials, together shear flesh and tough sinews. The cat's rough tongue also plays a role in meat eating.

Cats are pretty much nocturnal hunters, and their large eyes are perfected for gathering the maximum amount of reflected light available to them at night. In open country, especially, cats use their eyes to detect quarry. The sense of smell is fairly well developed, but not relied upon to the extent that it is by other carnivores such as dogs and weasels. The sense of hearing, on the other hand, is exceptionally keen, and is probably the greatest single asset to a cat's hunting. The *facial vibrissae,* or whiskers, are feelers associated with touch. No doubt, they warn a cat when it is getting into too thick underbrush, especially at night. A cat's brain is large and well developed, making the animal extremely alert and highly coordinated.

A HUNTER

As a rule, cats are solitary animals, traveling and hunting alone. Only at mating time do they accompany one another. Of course, the young follow their mother until capable of hunting for themselves. The lion is an exception to solitary living. Though it may live alone, twenty or thirty individuals frequently associate in a group known as a *pride*.

Cats usually restrict their movements to a home range inhabited by game upon which they can prey, and having suitable hideaways where they can retreat when not hunting. The size of the range depends on the species of cat. The bigger cats of necessity must have ranges that support the larger hoofed mammals on which they chiefly feed. For example, the home range of a lion troop may extend from 20 to 30 kilometers. A cat will expand its home range or move to another area if game becomes scarce. Cats are generally good climbers, although many of the larger cats keep mostly to the ground.

Cats prey on any animal that they are quick enough to catch and strong enough to subdue. Although cats are almost exclusively meat eaters, the lion and leopard are known to feed on vegetable matter, principally fallen fruit.

EVOLUTION

How did the cats develop the features that make them superb hunters? Many authorities believe that the highly adapted cat resulted from a long series of evolutionary changes. The ancestor of the cat was probably a primitive carnivore called a *creodont*. From the creodont there descended a group of forest-dwelling hunters known as the *miacids*. They were small, with long bodies and tails and short, flexible legs. Miacids in turn produced cats, civets, weasels, dogs, bears, and seals.

During the late Eocene and early Oligocene epochs, some 40,000,000 to 60,000,000 years ago, the miacids split into several evolutionary lines. Two of these lines evolved into catlike animals. One line gave rise to the stabbing cats. This line, which included the now-extinct sabertooth, was an evolutionary dead end. The other line evolved the biting cats, including modern cats and their direct ancestors.

Leonard Lee Rue III, Audubon/PR

The first true cats (represented by the genus *Felis*) appeared suddenly in the fossil record. The fossils date from the Pliocene epoch, some 13,000,000 years ago.

Today, cats are among the most widespread and successful of mammals. They are native to all major lands except Australia, Antarctica, Madagascar, and the islands of the Pacific Ocean. They are, however, most abundant in tropical regions.

There are at least fifty species of cats, belonging to the family Felidae, a mammalian family of carnivores. They are built on much the same plan, but for convenience are divided into the big and the not so big cats. The cheetah, however, is a somewhat different kind of cat.

BIG CATS

Members of the cat family that are considered "big cats" include the lion, tiger, leopard, and jaguar. The cheetah, though unusual in some of its features, is also often included in the group.

LIONS

The lion is the largest and most powerful of the wild cats. This "king of the beasts," as it is often called, is a strong, majestic-looking animal with a loud roar. It is feared by many other animals and often by man.

The lion prefers open country. Today the lion is limited to grassy plains, scrublands, and semidesert areas of Africa south of the Sahara. A few – no more than 200 – live in India's Gir Forest.

The lion's range was once much more extensive. Lions once lived in southern Europe, but as Europe became more forested following the last Ice Age, the lions lost their favorite habitats and gradually disappeared. A few lions, called Persian lions, may still exist in the Middle East, another area where they once roamed freely. Lions were once also found throughout much of Africa, but there, too, habitat changes and the pressure of hunting have severely limited their range.

The lion's fondness for open spaces makes it an easy target for hunters. Its population has decreased drastically, and lions are now legally protected from hunting in many areas of the world. African lions are found in several national game preserves where hunting is forbidden and the lion has a chance to replenish its numbers. The population of the Asian lion is so small that the species has been officially declared an endangered species.

Living in prides. Lions are the most sociable of the cats. Although lions, especially males, may live alone, they usually live in groups known as *prides.*

A pride typically consists of several lionesses – usually related to one another –

Leonard Lee Rue III, Audubon/PR

Right: the African lion, now a protected species. The male may live and hunt alone, but he is usually a pride leader. Left: a male charges his prey.

S.C.E.R.T., West Bengal
Library
Calcutta

and their young. Adult males become temporary members of the pride, living with the group for a few months or years. The males battle fiercely for possession of a pride. The winner dominates the whole group. When the leader shows signs of a decline of power and speed, he is driven from the pride by younger and more vigorous males who then take possession of the pride.

Hunting. Hunting is a cooperative affair. Normally the male circles a herd of zebra or wildebeest or other antelopes while the females wait in ambush. The hunters keep in communication by emitting grunts every so often. The male gets upwind of the quarry so that his scent is carried to them. He singles out several individuals and tries to cut them off from the rest of the herd, meanwhile driving the prey toward the hidden lionesses. Once a victim is within range, there is little hope of its escape. The lioness makes a short, high-speed charge, up to 80 kilometers per hour, and usually leaps at the shoulder area of the prey. The powerful forepaw with claws extended violently wrenches back the victim's head as the teeth sink into the back of the neck. The kill is swift and clean. Of course, the male is perfectly capable of making the kill, but his function is usually that of coordinating troop movements.

When the kill is made, the rest of the lions of the group join in the feast. The big cats gorge themselves on the meat, but since these animals do not crush the bones nor pick them clean, there usually remains enough to feed the jackals, hyenas, and vultures that always follow the lions.

Since lions eat until they are full, they may not kill again for several days. That they hunt only to satisfy hunger and not to kill for pleasure is attested to by the fact that lions are often seen resting near a herd of antelope or zebra or even walking through the herd.

African lions are found where herds of plains- and semidesert-dwelling hoofed animals congregate to feed and drink. In periods of drought, when the herbivores move to new feeding areas, the lions accompany them. During the hot season, they remain in shady places until well into the night before they commence to prowl. In wet or cold weather, the lions hunt in the late morning or afternoon.

In all truth, lions cannot be described as bloodthirsty or cruel. They beautifully exemplify the hunter's way of life and deserve the protection that is given the hoofed animals that serve them as prey.

A lion will not ordinarily attack a human unless it is startled, bothered, wounded, or diseased. Aged lions have been known to stalk and kill a person, but this is

Female lions and cubs make up most of the pride. Females become sexually mature at two years of age. They bear from two to six cubs per litter.

Leonard Lee Rue III, Audubon/PR

rare. Most aged lions—unable to pursue their normal prey—exist on scorpions, insects, and small rodents.

Reproduction. Sexually mature lions have no particular breeding season. When a female is sexually receptive, the sexes pair off and mate. After a gestation period of about 110 days, one to six spotted, helpless cubs are born. They are easy prey for leopards, hyenas, and other animals, and many do not survive. Those that survive grow quickly and when about one year old are able to make their own kills. They become sexually mature at about two years. Lions have a potential life span of 20 to 30 years, but they rarely reach this age in the wild.

TIGERS

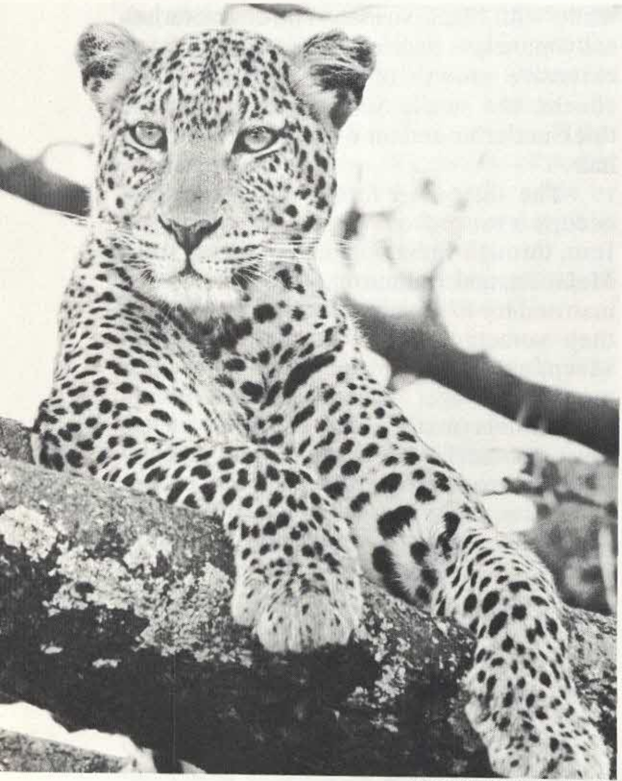
The body plan of the tiger is very much like that of the lion. Tigers are about the same size as lions. Externally, however, the two are quite different. The tiger has a ground color of reddish orange striped with black. Some specimens may be dark, others quite light in coloration. Rarely, one may be white with black stripes. The characteristically maneless tiger often possesses a fairly extensive growth of long hair about the cheeks and neck. *Siberian tigers* have a thick underfur and an overcoat of long pale hair.

The tiger is a forest dweller. Tigers occupy a range from the Soviet Union and Iran, through India, China, southeast Asia, Malaysia, and Indonesia. Tigers are shy of man and try to remain out of his sight. Since they sometimes feed on cattle, horses, sheep, and goats and infrequently become man-eaters, tigers have been extensively hunted over many areas. They have also been hunted for their pelts. The tiger of temperate and tropical Asia is an endangered species.

Hunting. Tigers, especially older individuals, can subsist on locusts, fish, scorpions, crabs, and frogs. Their usual prey, however, is larger game, including wild hogs, antelopes, water buffalo, and various kinds of deer. When on the prowl, the tiger keeps to game trails, man-made paths, and

The tiger lives in forests throughout Asia. Tigers spend their days resting in the shade or swimming. They usually hunt at night.

Buck Reeves, Audubon/PR



Leonard Lee Rue III, Audubon/PR

The leopard is smaller than the lion or the tiger. It is a very quick animal that can climb trees well. Leopards can be recognized by their characteristic black blotches or rings. They are found in Europe and Asia. Some leopards are completely black: these are the animals called black panthers.

the banks of rivers, preferring not to make its way directly through heavy vegetation.

The tiger's sense of smell is poor and its eyesight is not much better, but its hearing is superb. It is on this fine hearing that the big carnivore mainly depends for hunting. Let a deer or antelope stand perfectly still in the forest gloom, and the tiger will pass it by or may even look in its direction without distinguishing it as possible prey. But if the animal flicks an ear, moves a leg, or makes a sound, the prowling tiger becomes aware of it.

Creeping or stalking stealthily, and remaining unseen, unheard, and unsmelt by its intended victim, the tiger gets to within rushing distance. Then, with several bounds, it is on the prey. The big cat drags its kill to a sheltered spot and eats until full. Afterwards, the tiger rests nearby, returning from time to time to feed on the kill, even if the meat is quite rotten, until little remains.

Reproduction. Tigers, unlike the social-living lions, are ordinarily solitary and independent creatures. However, the animals sometimes live in pairs for long periods. Mating takes place when the tigress is receptive, which may be at any time of the year. The gestation period lasts from 105 to 109 days, and one to five cubs are born. Two cubs are usually born in one litter. The young remain with the mother until they are half grown. Tigers may live about nineteen years.

LEOPARDS

The leopard, another big cat but somewhat smaller than the lion or tiger, is one of the most quick-reacting of mammals, becoming quite fearless and fighting savagely when cornered or otherwise bothered.

Those leopards that inhabit semidesert regions or rocky and treeless areas tend to be of large size and pale colored. Leopards are about 1½ meters long and weigh about 90 kilograms. In forested lowland and mountainous districts, leopards are usually smaller and have a darker coat profusely patterned with large black blotches and rings. In certain areas, some of the leopards are black and are called *panthers*.

Leopards have a wide range that includes all of Africa, except the Sahara and Kalahari deserts, and extends east from the Black Sea through India to Burma and Malaysia and north through China.

Hunting. A leopard frequently conceals itself by day in a cave or other den or in a leaved tree. It usually hunts by itself, but occasionally two of the beasts prowl together.

Since the leopard is an expert at tree climbing, it spends a great part of its time in trees, where it hunts small tree-dwelling animals, especially birds and monkeys. It cleverly stalks its quarry through the trees or waits in ambush until an unwary creature comes to within springing distance. Baboons are sometimes preyed upon, but these are most often sick or solitary individuals or stragglers cut off from the main troop. A troop of baboons can usually ward off the attacks of the leopard. Deer, antelope, pigs, and young water buffalo are also natural game for this carnivore. The leopard often hides itself in a tree or rocky outcrop above a water hole or game trail, dropping upon its prey from the site of ambush. If the leopard's victim is so large that it cannot be entirely eaten at one time, the big cat drags the remainder of the carcass up into a tree, apparently as a protection against hyenas. One observer saw the remains of a young buffalo—over 40 kilograms of flesh and bone—hung by a leopard in the branches of an acacia tree. The branches were about three meters above the gound.

Reproduction. One to four cubs, but usually two, are born after a gestation period of ninety-two to ninety-five days. They remain in company with the female for the first six months of their lives. Leopards are known to have a life span of at least twenty-one years.

LEOPARDLIKE CATS

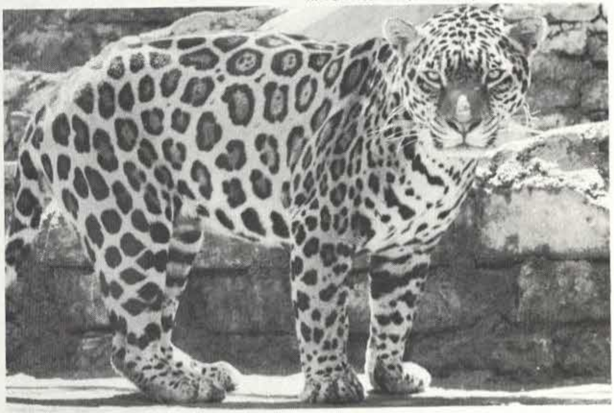
The *clouded* and *snow leopards* are not true leopards, but are leopard-size and decorated with dark blotches and broken rings. These attractive felines are secretive creatures, rarely encountered by man. The clouded leopard, which has an exceptionally long tail, is an arboreal carnivore of southeastern Asia's dense forests. The snow leopard lives in the high altitudes of central Asia—from the Himalaya to the steppes and Altai Mountains. Its long, soft, plumelike hair covers a dense woolly underfur.

JAGUARS

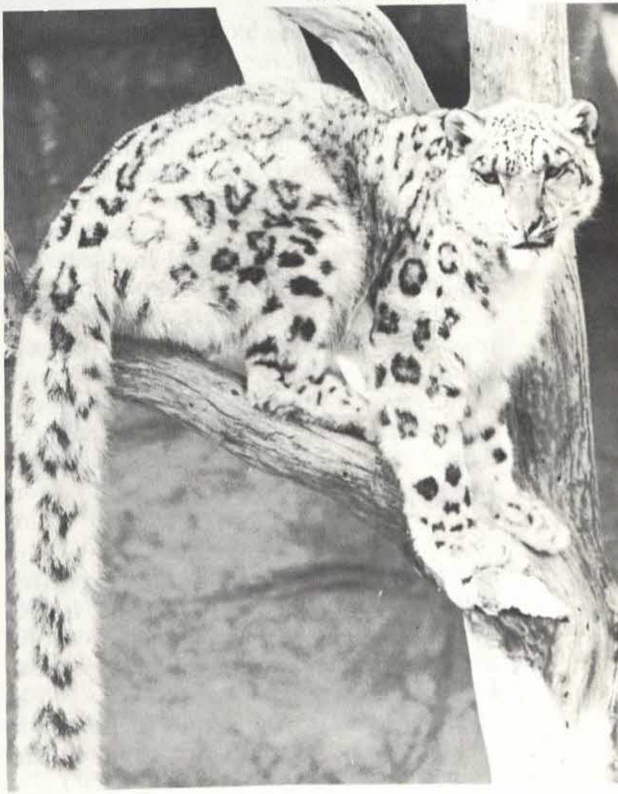
The jaguar is patterned somewhat like the leopard, but is more stocky and has a larger head. It is the big cat of the New World, ranging from southern Arizona and New Mexico to lower Patagonia. Though the jaguar lives in arid country and mountainous regions, it prefers the tropical lowlands, expecially near river banks.

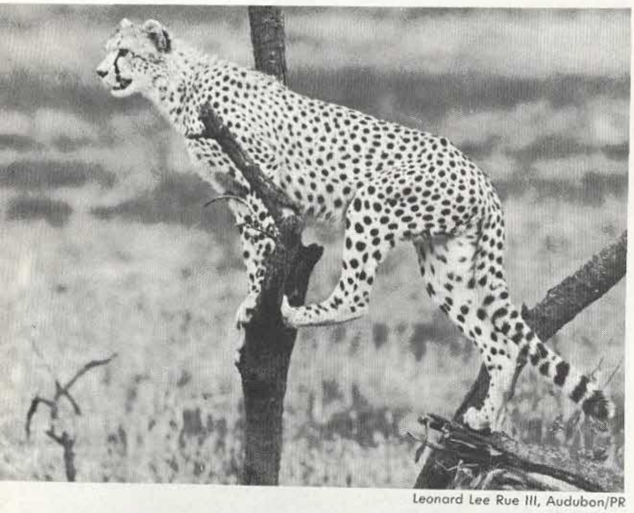
Top: the jaguar resembles the leopard. Jaguars live in North and South America. They prefer tropical lowland regions. Bottom: the snow leopard lives in the highlands of central Asia. Its thick light-colored coat protects it from both heat and cold. It has thick paws to keep it from slipping into the winter snow. The snow leopard is a good climber. It prefers to rest in high places such as rock ledges and tree limbs.

R. Van Nostrand, Audubon/PR



James R. Purdue, Audubon/PR





Leonard Lee Rue III, Audubon/PR

The cheetah is the fastest sprinter on earth. It once roamed over large areas of Asia and Africa, but is now limited to parts of Africa. It is quite different from other cats. For one thing, its claws cannot be pulled back. Also, the cheetah's head is small, and its paws are narrow—two other uncatlike features.

The jaguar is an expert at catching fish. It lies on a river bank or overhanging branch and with extended paw scoops up its prey as they come within reach. The cat swims well and will pursue turtles in the water. It attacks capybaras (rodents) and tapirs that come to drink. The jaguar also climbs trees after monkeys. In fact, the cat spends much time in the trees when the lowlands are flooded during the rainy season.

The male jaguar seems to assist in providing food for the young and protects them from possible danger. The kittens, usually two or three, are born after a gestation period of approximately one hundred days.

CHEETAHS

The cheetah, which is as big as a leopard, is a plains and desert carnivore of Africa and India. Its sandy brown coat is profusely spotted with black. This beautiful and easily tamed animal has been semidomesticated in India for centuries. Wild cheetahs that are young but experienced at making their own kills are captured and trained for hunting.

The cheetah has the distinction of being the world's swiftest ground-running animal. The cheetah's lithe, streamlined body is supported on long, slender legs. The head is small and the feet narrow. The stout claws cannot be drawn back into sheaths. Quick to break into a run, the cheetah can reach 70 kilometers per hour in only two seconds after starting. At full speed the animal attains a little over 110 kilometers an hour, swifter than the fastest greyhound. Such a pace, however, cannot be long maintained.

The cheetah, like other cats, is a stalker. With belly to the ground it creeps to within 100 meters of its quarry. Then, it puts on its enormous speed to run down the prey over a short distance. If the intended game—a rodent or a medium-sized or small antelope—is not caught within 500 meters, the cheetah gives up the chase. It does not have the necessary endurance to be a long-distance runner. The running cheetah can agilely change direction and usually makes the capture regardless of how much the prey turns in its flight to escape. The cheetah's long tail serves as a rudder in these maneuvers. Cheetahs hunt by sight during the day or on moonlight nights.

LESSER CATS

The lesser cats vary in size from the meter-high puma to the small house cat. They can scream or yowl but do not have the vocal apparatus to roar as the big cats do.

PUMAS

Pumas are also called *mountain lions, cougars, catamounts,* or *painters*. They are one of the most widely distributed of mammals. They were found from Canada's northern forests to the southern tip of South America. Unfortunately these magnificent animals, which once occurred over much of North America, have been widely hunted until they now inhabit only the more remote areas of the western third of the continent. Some may still be found in Florida.

The tawny, trim puma hunts deer, tapirs, small mammals, and birds in all kinds

New York Zoological Society

Pumas were once found over most of North America. Today, they are found only in the western third of the continent.

of country, from swamps and rain forests to brushy and grassy plains and arid, mountainous terrain. Traces of the cat have been found at 5,600 meters in the Andean highlands.

Active both by day and night, the puma dens up in a cave, a fissure in the rocks, or a clump of dense vegetation. The puma's home range covers many square kilometers, and the animal is known to travel as much as 30 kilometers in a single hunt.

Like all cats, the puma is a stalker and springer, cautiously taking advantage of all possible cover to get within a bound or two of its prey before making a leaping charge. After eating its fill, the cat covers over any remains of the kill and returns to it a day or so later. Pumas are known to track humans, apparently out of mere curiosity. But reports of unprovoked assaults on humans have not been authenticated, and are indeed exceedingly rare, it they occur at all.

OCELOTS AND OTHER AMERICAN CATS

The ocelot, a smaller cat, is handsomely marked with dark blotches, bars, and small rings. It is found from the extreme southern United States to Paraguay.

Ocelots are nocturnal animals of open country or closed forest. The animal typically makes its den in a rocky cave or hollow tree. Ocelots are known to hunt in pairs for small vertebrates of all kinds, especially snakes. They mark their hunting grounds by piling their excrement at certain fixed places.

The *jaguarundi* is another American

cat. It is a uniformly gray or brownish red cat, having a slender, elongated body, short legs, and a long tail. It is a thick-brush cat, somewhat larger than a house cat, of South, Central, and southern North America.

American cats also include the *margay*, of South and Central America. The margay is small but similar to an ocelot in shape and pattern. Several other spotted and striped cats, such as the *Andean highland cat* and the *pampas cat*, also live there.

AFRICAN AND ASIAN CATS

In Africa and Asia are a number of small to medium-sized cats, similar in appearance but varying their behavior to fit the habitat in which they live. They inhabit forests, open woodlands, brushy plains, and deserts, hunting all kinds of small game.

The *golden cats* are beautiful reddish-brown felines living in the mountainous forests of southern Asia and Africa. They may grow to the size of a small leopard. Among the smaller Oriental spotted cats are the *leopard cat, rusty-spotted cat, marbled cat,* and *fishing cat*. Small cats that are desert-adapted, having pale, sandy colored coats, include the *pallas cat* of central Asia, the *desert cat* of southern Asia, and the *sand dune cat* of the Middle East and Africa. Felines that are patterned like our domestic tabby cats include: the true *wild cat*, still found in remote areas of Europe; the *black-footed cat*, which is an African cat only 35 centimeters long excluding its 15-centimeter tail; and the *African* (or *Egyptian*) *wild cat*, from which our house cats have probably been derived. In southeast Asia there are two plain-colored, short-legged felines with stubby tails – the *flat-headed cat*, which is dark brown above and white below, and the *Bornean Bay cat*, which is a reddish chestnut all over.

LYNX

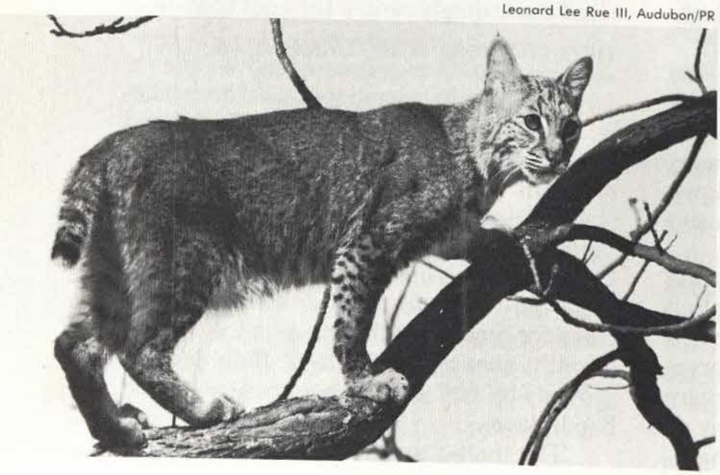
The lynx is a large, powerful cat. The lynx is heavy-bodied and may measure up to one meter in length. Its grizzled gray-brown fur is rather long. It has a short tail that juts from high hindquarters that gently slope toward the lower forequarters. A ruff of hair is at the throat, and hair tufts project from the high, pointed ears. The cat's paws are wide and padded for travel in snow.

There are lynx populations throughout Europe, Asia Minor, and northern Asia. It is found in the northern parts of the United States (including Alaska) and in various parts of Canada.

The lynx is primarily a forest animal. Sometimes, if food becomes scarce, the cat will prowl far out on the tundra. Its large, fluffy feet serve effectively as snowshoes that pace over the snow without sinking in. The animal climbs trees and swims well, but does its hunting on the ground. Though powerful enough to pull down a deer, the lynx preys chiefly on the snowshoe hare. When the hares decline drastically in numbers every seven to ten years, hundreds of lynxes die of starvation.

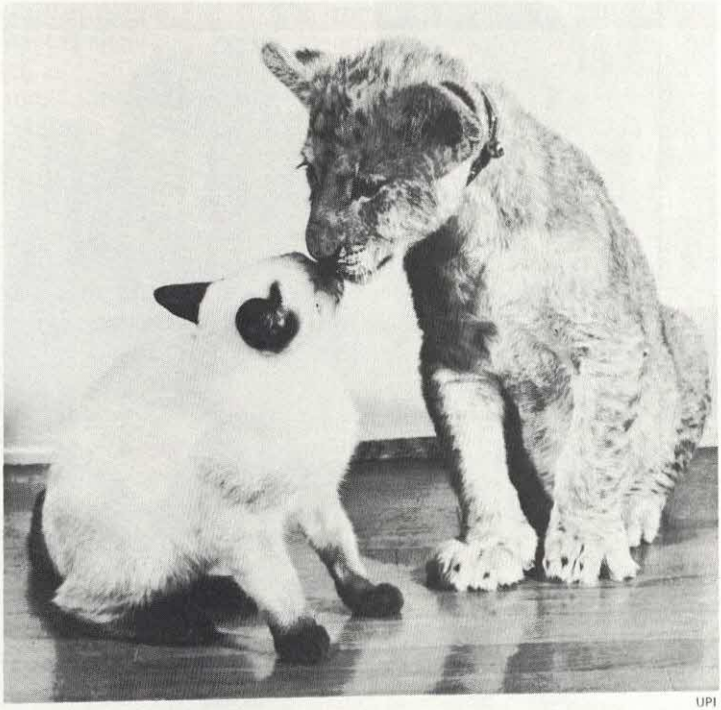
Lynxes are usually solitary, but sever-

Leonard Lee Rue III, Audubon/PR



The bay lynx, better known as the bobcat, lives in the rugged mountainous regions of the United States and Mexico. It preys on rabbits and rodents.

A three-month-old Siamese is nuzzled by a three-month-old lion. Domestic cats were probably derived from the African wild cat. The many breeds vary in size, coloration, and type of hair.



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al of the animals are sometimes seen traveling or hunting together. The lynx makes its lair in a hollow log, or in the shelter of a fallen tree, or under an overhanging ledge. Here the two to four kittens are born to the female, who mates in the late winter.

The *bobcat,* or *bay lynx,* is a smaller, short-haired lynx that inhabits forests, swamps, deserts and mountainous country of the United States and Mexico. It hunts rabbits and other small animals and may travel nearly 40 kilometers in a night over an irregular hunting route. The *Isabelline lynx* lives in southern Europe.

CARACALS

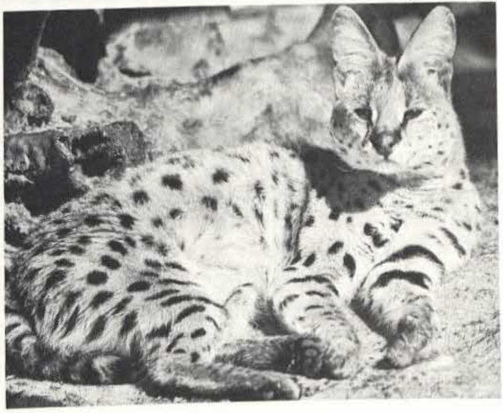
In the hot and dry areas of Africa and southern Asia is found the *caracal,* a slender, lynxlike feline with a short, reddish brown coat. Long plumes of hair tip its ears. A very agile and quick animal, the caracal can catch a gazelle and captures flying birds by leaping into the air and knocking them down. Another lynxlike feline, the *jungle cat,* prowls the forests, dry scrub, and tall grass areas of eastern Asia and northern Africa.

SERVALS

The *serval* is a somewhat untypical feline of equatorial Africa. It is similar to a lynx in being long-legged, long-eared, and short-tailed, but is a more slender animal with golden buff fur strikingly blotched with black. The serval lives in the long grasses of the open plains and hunts small game.

The serval of equatorial Africa is a fast runner that hunts both during the day and at night.

Jeanne White, Audubon/PR



The trunk is the elephant's chief tool. Here an Indian elephant uses its trunk to splash water on itself and its young. Elephant young stay close to their mothers for three years.

Rapho/PR

ELEPHANTS

Elephants are the largest land animals existing today. Of all living animals, only some whales are larger. Today elephants are found in Africa, India, Sri Lanka, and adjacent areas of Asia.

Elephants are tall animals with large heads and bodies. The head has two distinguishing features: a very long trunk and ivory tusks. The trunk is really an elongated snout and upper lip. It is the animal's chief tool. The tusks are elongated, specialized teeth that the animal uses as a weapon and for digging.

Although the skull is large, the bones have many cavities and air spaces, making it less heavy than if it were solid bone. The backbone, to which are attached many ribs, serves as a girder balanced on the strong forelegs. The large, heavy head counterbalances the weight of the body. The hind legs provide the chief thrust in walking or running. Elephants, despite their huge size, walk on their toes. There are usually four toes on each foot.

TWO TYPES

Elephants are members of the group of hoofed mammals, or ungulates. They make up the order Proboscidea. This order has only two genera: *Elephas*, which includes the Asian elephant, and *Loxodonta*, which includes the African elephant. There is only one species in each genus.

The two species—the African elephant *(Loxodonta africana)* and the Asian elephant *(Elephas maximus)*—differ in size and in the size and structure of the ear and tusks. The African elephant is slightly larger than the Asian elephant.

African bulls normally reach three to four meters, and a weight of 5,000 to 7,500 kilograms. Occasionally individuals taller than four meters have been found. Females are about one-half meter shorter, on the average, than the bulls. Asian bulls usually attain a height of three meters. One consequence of the African elephant's greater size is that it rarely lies down after reaching maturity. As the animal grows older and larger, it becomes more and more difficult for it to lift its great bulk to a standing position once it has reclined. It may spend the last thirty or forty years of its life on its feet – even while sleeping. Asian elephants, on the contrary, lie down quite regularly. Only the old ones sleep on their feet.

There are a few other differences between African and Asian elephants. African elephants have a somewhat sway-backed appearance, with the high point of the back near the shoulders or rump. They have longish faces and large, fan-shaped ears. Asian elephants, on the other hand, have a straight or arched back with the high point near the middle, small faces, and smaller, triangular-shaped ears.

TRUNK

The elephant's trunk is a powerful, muscular organ. From an exaggerated, pig-like snout that was present in the animal's ancestors, the elephant fashioned a trunk that was capable of grasping objects. The powerful muscles needed to manipulate it arose chiefly from those parts of the facial muscles that other mammals use to move the sides of the nose. As a consequence, the trunk of modern elephants is far more satisfactory than a long neck, for not only can it reach the ground but it can also be moved upward, backward, and sideways.

The elephant can do a great many things with its trunk, It uses the organ, for one thing, to draw in water. However, contrary to popular belief, it does not actually drink water through the trunk. Water is sucked into the organ and is then sprayed into the mouth.

The trunk is also used to convey food to the mouth. By means of this useful organ, the elephant can feed on the vegetation on the ground and in the trees above its head. Among the big animal's favorite foods are the tender twigs and branches from the upper limbs of trees. Occasionally the twigs are too high for even the trunk to reach. In this case, the animal solves its feeding problem in a remarkably simple way: it pushes the tree over, using its head as a battering ram.

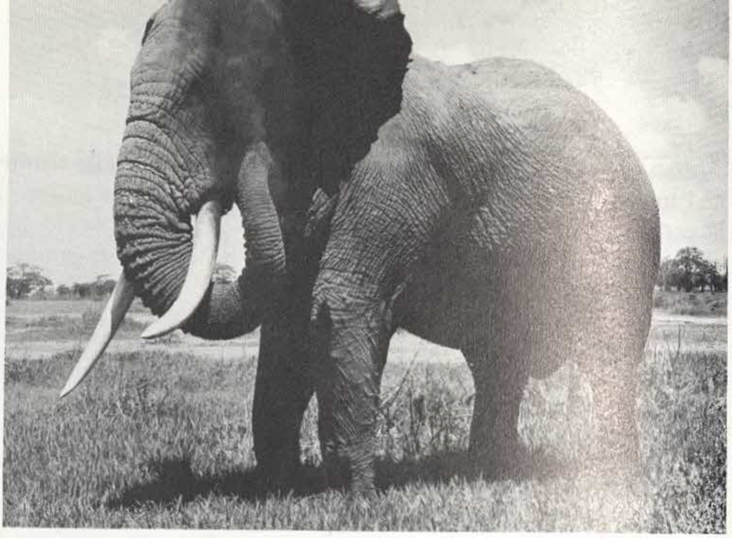
The trunk of the elephant serves as a sort of fifth limb, and a very powerful one, too. With it, the animal has been known to lift as much as four or five hundred kilograms. It does not carry heavy loads on its trunk, however. A ponderous log, say, would be lifted by the trunk to a position across the tusks and then held in place by the trunk.

Strong as the elephant's trunk is, it is capable of quite delicate work. On the end of the elephant's trunk, there are one or two lobes, which the animal can manipulate with great dexterity. The lobe of the trunk is also a very sensitive organ of touch.

The trunk serves as the elephant's organ of smell, and the animal depends to a considerable extent on its sense of smell – one of the most acute in the animal kingdom – to keep it in touch with what is going on. The trunk is constantly in motion, sniffing the air and inspecting the objects in the immediate vicinity.

The trunk developed through one of those experiments of nature whereby, as an animal changed in size or habits, it changed its means of getting food. Since the early elephants were browsing animals, it seems that as they grew in stature, they either had to increase the length of their necks or find another way to reach the ground with their months. The head was so heavy that it was impossible to grow a longer neck and the accompanying muscles to support it. Instead, the early elephants developed elongated lower jaws.

As the lower jaws lengthened, the nose and upper lip gradually grew beyond the upper jaw. But as the snout, or trunk, increased in length, the necessity for the long



An African elephant giving itself a dust bath. Elephant skin is thick and dry but sensitive. Elephants will often throw dust over themselves to dislodge insects that may be on their heads and backs.

Donald Patterson/PR

lower jaw disappeared. As a result, this jaw began to shorten, and the trunk became the means for getting food. The two remaining incisor teeth of the elephant's upper jaw developed into continually growing tusks. The tusks were weapons and also served perhaps to dig up roots.

INTELLIGENT WORKERS

Elephants are nomadic. They travel in herds of two hundred or more under the guidance of a big bull. The diet is strictly vegetarian. The herd moves from one place to another in search of fodder. The big animals lumber along, in single file, at about 10 kilometers per hour.

There is no doubt that the animal is one of the most intelligent of the mammals, but there is much disagreement as to how it compares with the dog, the horse, and the great apes. The intelligence of elephants is attested in many ways. They have been taught to understand as many as twenty-five different commands. The big animals have been known to make tools for their own use. They remove branches, strip them of all but the topmost leaves, and use them as fans to brush away flies. Sometimes they pull up stakes and use them as back-scrapers. In passing spears to their riders, the animals have been trained to present them handle first. When traveling through a wooded area, an elephant will protect its rider from low-hanging twigs and branches.

Elephants are noted as work animals. Among other things, they have been used for centuries in logging operations in India and Burma.

MUSTH AND REPRODUCTION

At certain times of the year, African elephants and Asian male elephants go into a condition of excitement known as *musth*. During such periods, a strong-smelling liquid runs from glands near the eyes and the animals seen ill-tempered and excitable. The exact meaning of musth is not known, though it is thought to have some sexual function. Elephants tend to mate more frequently during musth than at other times, but they may mate at any time. The period of gestation is about 21 months. The females bears a single calf at each birth. She is often assisted at the birth by other female elephants, then known as "aunties."

An elephant calf stands about one meter tall, weighs about 100 kilograms, and is covered with hair at birth. The calves are suckled on a single pair of mammaries between the mother's forelegs.

EVOLUTION

Modern elephants are two descendants of a long line of animals that goes back some 40,000,000 to 50,000,000 years. That line includes the mastodons, the mammoths, and numerous more primitive elephantlike types.

The earliest known member of this line was *Moeritherium* of Africa. A comparatively puny creature, it stood only 50 centimeters high. It possessed small tusks on both upper and lower jaws, and it probably had a short snout, like that of a tapir. From this type at least two branches of elephant development arose.

One branch led to the *Dinotherium* of Eurasia and Africa. It was a distinct type of elephant having down-turned tusks on the lower jaw. It became extinct perhaps less than 1,000,000 years ago.

The other branch led to the *Gomphotherium* of Africa, Eurasia, and North America. This animal, which had elongated, tusk-bearing upper and lower jaws, flourished some 25,000,000 years ago. From this long-faced elephant came *mastodons,* (some of which had a lower as well as an upper pair of tusks); mammoths; and present-day elephants. The mammoths differed from the mastodons in having a much higher and shorter head and a short, tuskless lower jaw. Our modern elephants resemble the mammoths more closely than the mastodons.

Woolly mammoths were depicted quite frequently in Stone Age drawings. Well-preserved carcasses of these huge animals have been found embedded in the soil of Siberia. Apparently they had bogged down in deep mud, which later became frozen.

In the early part of the nineteenth century, a mammoth was discovered in a marvelous state of preservation near the mouth of the Lena River, in Siberia in the Soviet Union. Its flesh and hair and internal organs were intact. In fact, its last meal was still undigested in its stomach. Its brain was quite uninjured.

Mammoths measuring four meters in height have been found, but the average seems to have been about three meters. These animals were comparable in height, therefore, to the elephants of the present day. Mammoth tusks were very long—in extreme cases, over three meters. The mammoth was covered with very long hair that almost reached the ground. The tail was short. A tuft at the end was provided with stiff bristles. The ears were small and they were covered with fur.

Apparently the mammoth was the only member of the elephant family that became adapted to conditions of extreme cold. In France, it maintained itself until toward the very end of the glacial period. It may have survived even longer in the tundras of northern Siberia.

HYRAXES

Few people have ever heard of hyraxes, much less seen them. Hyraxes are plump, furry, rabbit-sized animals that resemble rodents. Actually, hyraxes are close relatives of the elephants.

Hyraxes are less than one-half meter long and they weigh about four kilograms. They have long incisor teeth that correspond to elephant tusks. These incisors grow throughout the animal's life.

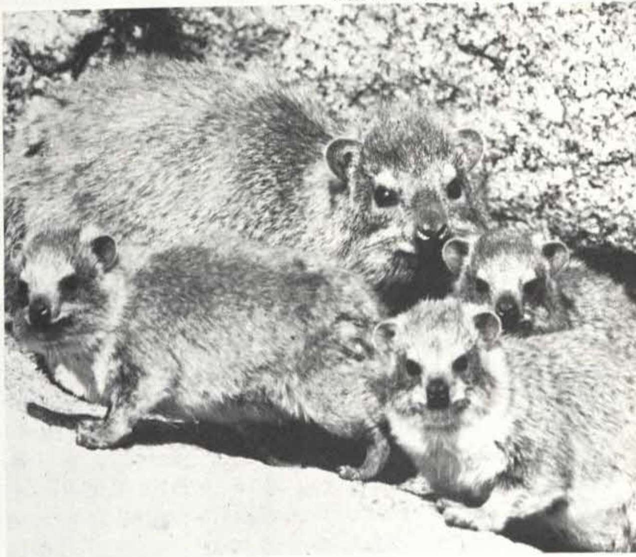
Hyraxes are herbivorous animals. They are unique among the mammals in having two appendixes. The larger of the two is used to break down cellulose, the very hard-to-digest ingredient of plants.

The gestation period is about seven or eight months long. Depending on the species, one to three young are born.

There are three genera of hyraxes: the tree hyraxes, which live in the forests of central and southeastern Africa; the rock hyraxes, which live on the mountains, plains, and steppes of Africa from Ethiopia to Angola; and the cape hyraxes, which are found along the Nile and across central and southern Africa.

Strange as it may seem, these furry, rabbit-sized animals known as hyraxes, or conies, are related to elephants.

These Daniel, Audubon/PR



Dave Repp, Audubon/PR

Leonard Lee Rue III, Audubon/PR

Domestic pigs are important commercially throughout much of the world. Left: a domestic pig with its litter. The young may reach maturity before the age of one year. All domestic pigs are derived from the European wild boar (above). A related species of pig, the warthog of Africa, is shown on the opposite page.

PIGS AND HIPPOPOTAMUSES

"Dirty as a pigpen." "Eat like a hog." Is the pig being unjustly criticized or are these expressions fitting to describe messiness and overeating? Pigs, in fact, are cleaner than many other farm animals. And, they do not typically overeat.

Pigs and peccaries, as New World pigs are correctly called, are medium-sized mammals. They have a giant relative—the hippopotamus—the second largest land animal in the world.

PIGS

Pigs are not highly specialized and therefore can adapt to many environments. This probably accounts for their success in establishing a worldwide distribution.

Pigs are from 50 to 100 centimeters long and 25 to 100 centimeters tall. They may weigh more than 300 kilograms. They generally have heavy bodies and longish, rather pointed heads. Most species have a movable, squarish snout with a strong tip with which the animals root for their food. Pigs and peccaries are omnivorous.

Pigs and peccaries are social animals. They typically live in small groups. Body contact between group members is frequent. Pigs living in the wild usually have one litter per year. After a gestation period of 4 or 5 months, two to 14 piglets are born. They can live as long as 25 years.

Bush pigs *(Potamochoerus porcus)* are found in all parts of Africa south of the Sahara and on the island of Madagascar. They are small and have sharp canine teeth. Some are handsomely colored.

The warthog, *Phacochoerus althiopecies*, is an agressive animal found in open areas in Africa. It has rather large skin warts, well-developed canine teeth, and calloused wrists on which it walks.

A very large pig, the giant forest pig, *Hylochoerus meinertzhageni*, is found in a few places in Africa.

A pig native to southeast Asia, the babirusa *(Babyrousa babyrousa)* has canines that curve backwards to such a large extent that they reenter the upper jaw.

Wild boars (genue *Sus*) are found in Europe, tropical Asia, and northern Africa. The domestic pig is derived from a wild boar species—*Sus scrofa*. The many varieties of domestic pigs are important commercially throughout most of the world. They are a source of pork, ham, bacon, sausage, and many nonfood products, including soap, leather, and some drugs.

PECCARIES

Peccaries are the pigs of the New World. They resemble Old World pigs but

Satgur, South African Tourist Corp.

differ from then in internal anatomy.

The peccaries are small, up to 55 centimeters tall and weighing 20 to 30 kilograms. They lack external tails. Two to four young are born after a gestation period of about 150 days.

The collared peccary, *Tayassu tajacu,* has a yellow stripe behind its head. The rest of its coat is dark brown. It is found from the U.S. Southwest to central Argentina.

The white-lipped peccary, *Tayassu albirostris,* ranges from Central America to central Argentina. It lives in large herds.

HIPPOPOTAMUSES

The word "hippopotamus" comes from two Greek words meaning "river horse." The animal is a river-dweller, indeed, but the "horse" part of the name is not particularly appropriate, because the hippopotamus is allied to the pig family.

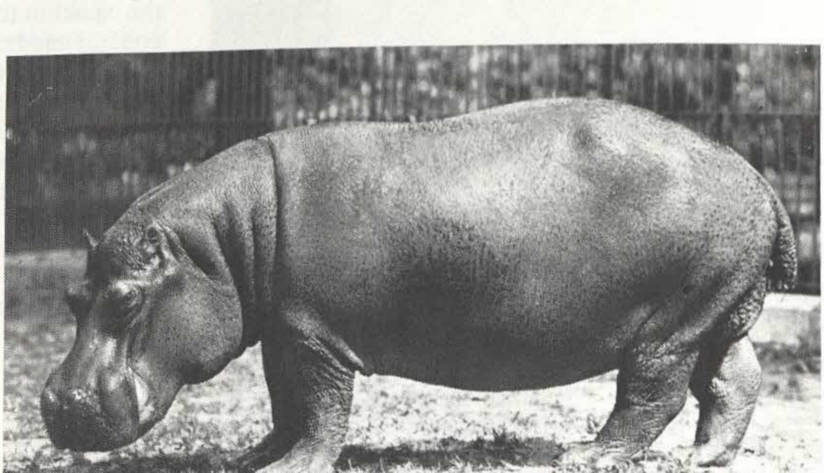
The hippopotamus is the second largest land-living animal, by weight, in the world. The average specimen weighs about 3,500 kilograms. The massive head alone may weigh a 1,000 kilograms. The animal is from 3½ to 4 meters in length and stands over one meter at the shoulder. The huge, barrel-shaped body is supported by short, pillarlike legs. The skin is very thick over most parts of the body.

Hippos live in herds of twenty to thirty individuals. Each herd keeps to the river most of the day. Hippos can remain under water for as long as thirty minutes. The normal interval, however, is five to ten minutes. The animals can float or sink to the bottom, sealing their nostrils and ears voluntarily. Hippos are excellent swimmers. They can also walk along the river bottom at quite surprising speed – over 10 kilometers per hour, according to certain authorities. The hippo feeds voraciously on river growths, and may consume about two hectoliters in a day.

At night, the members of the herd occasionally leave the river to feed along river banks. On land, the animal can walk about as fast as a man and it can even gallop after a fashion. While it is on land, special skin glands pour forth on oily, reddish liquid that prevents the skin from drying out.

Hippos mate once a year. The bulls fight savagely at mating time. After a gestation period of about nine months, a single calf is born. It weighs about 50 kilograms, and its weight increases rapidly. It travels on its mother's back.

There are two living species belonging to the family of the Hippopotamidae. The common hippopotamus, *Hippopotamus amphibius,* once had a wide range, but is now restricted to a portion of Africa, north of the Republic of South Africa. The pigmy, or Liberian, hippopotamus, *Choeropsis liberiensis,* is found in Liberia and Sierra Leone. It stands less than one meter tall, is about two meters long, and weighs about 180 kilograms.



The hippopotamus, a giant pig, is the second largest land animal, by weight, in the world.

CAMELS AND LLAMAS

To many people the word "Sahara" brings to mind camel caravans crossing vast arid expanses. Indeed, camels have often been pictured as beasts of burden that hardly ever tire or thirst while crossing the desert. This image, however, gives only a limited view of the camel.

Camels and llamas are cud-chewing, even-toed, hoofed mammals. They are both classified in the camel family. Camels are distinguished by one or two large humps on the back.

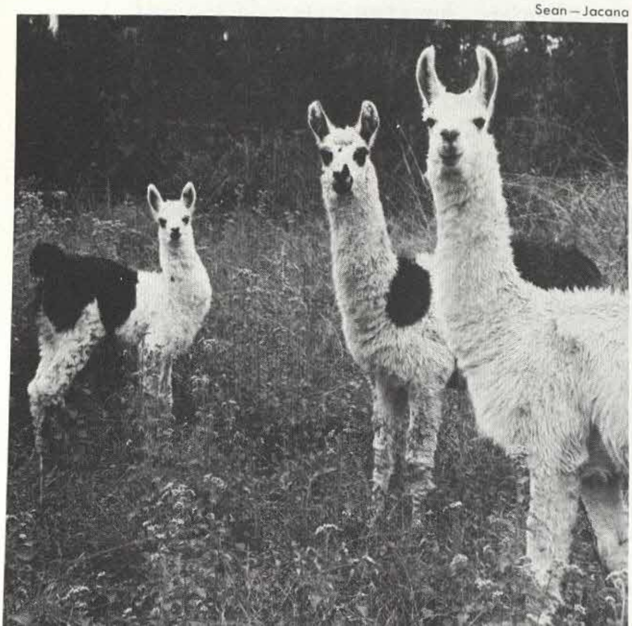
The oldest remains of camel-like animals were not found in Asia or North Africa, the regions where the modern camel is found. Interestingly enough, the oldest fossil pre-camels were found in North America. The oldest remains indicate that a camel ancestor that lived 58,000,000 years ago was a very small animal—about the size of a rabbit.

The main line of camels is believed to have descended from an animal called *Procamelus*. The modern camels did not evolve in their present locations. They migrated from North America to North Africa and Asia about 2,000,000 years ago. By the end of the Pleistocene epoch—about 10,000 years ago—there were no more camels in North America.

Llamas migrated from North America to South America as recently as the last glacial period.

The alpaca is a member of the camel family, and is a subspecies of llama. Alpacas, unlike llamas, are not used as pack animals—they are sheared for wool.

Sean—Jacana



CAMELS

Camels belong to the genus *Camelus*. They are large animals. Camels may grow to three and one-half meters long and two to two and one-half meters high. They may weigh up to 650 kilograms. They have callouses on the feet, legs, elbows, knees, throat, humps, and tail. Heavy eyelids and eyelashes protect their eyes from dry desert winds. There is a pair of glands at the back of the head that secretes a black creamy substance.

The humps on the camel's back are for food storage. Instead of having fat distributed throughout the body, it is concentrated on the back. This allows most of the camel's body—without fat insulation—to lose heat rapidly—an adaptation for its life in a warm environment.

Stories about camels never needing to drink are greatly exaggerated. The animals can, however, endure lack of water for prolonged periods of time. A camel can sometimes lose up to 22 per cent of its body weight through water loss. After a long drink, however, the camel's body begins to fill out once again. The camel loses water from its body cells, not from its blood, where it is necessary for temperature control. A variety of special body mechanisms—including low urine output—enable the camel to tolerate wide changes in water content and body temperature.

There are two kinds of camels: the two-humped, or Bactrian, camel, *Camelus ferus bactrianus*, and the one-humped camel, or dromedary, *Camelus dromedarius*.

The Bactrian camel is found in central Asia and the Middle East. A wild form, *Camelus ferus ferus*, with smaller, more upright humps, is found only in central Asia. The dromedary is found in the Middle

East and North Africa. Where the ranges of the dromedary and the Bactrian overlap, hybrids – often fertile – occur.

Camels have a very short mating season. The female camel carries her unborn young for somewhat over a year. A single young is born while the female stands. The newborn camel can walk within a few hours and by the time it is two days old it is very sure-footed. The young camel is nursed for over a year.

LLAMAS

Llamas are the smaller members of the camel family. They are generally one to two meters or a little more in length and from 70 to 130 centimeters high. They can weigh up to 75 kilograms. Llamas do not have humps on their backs.

There are two wild kinds of llamas. The guanaco, *Lama guanicoë*, is the larger of the two wild types. The domestic llama, *Lama guanicoë glama*, and the alpaca, *Lama guanicoë pacos*, are derived from this wild type. The vicuña, *Lama vicugna*, is the smaller wild type of llama.

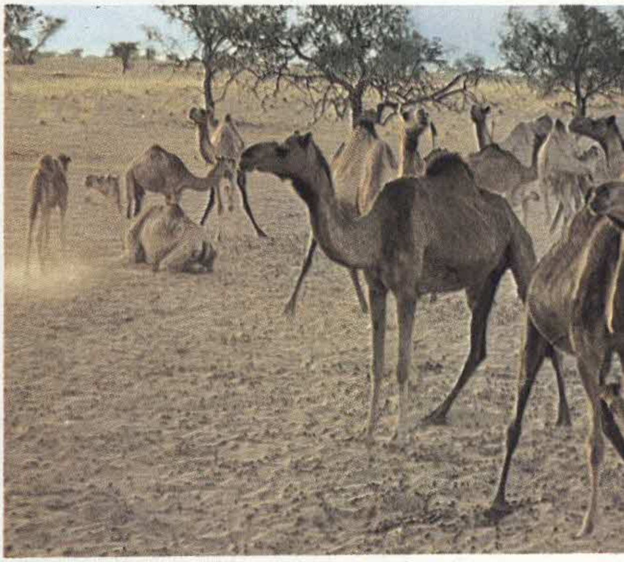
Guanacos are rare today. They live only in the high mountains of Peru, Chile, and neighboring areas.

The male domestic llama is used as a pack animal in the high mountains of South America. The female is not used as a pack animal, but is sheared for wool, although the wool is not very valuable.

The alpaca, on the other hand, is not used as a pack animal, but is sheared for its valuable wool. Its wool is much longer than that of the domestic llama.

The vicuña has an even more restricted range than the guanaco. The Indians living high in the Andes use the vicuña as a source of wool.

During the breeding season llama males are agressive toward one another and also toward females that are reluctant to breed. Females are kept in harems of 15 to 20 individuals headed by one male. The gestation period is about 11 months. Usually, only one young is born at a time. All four types of llama will interbreed in captivity. The crosses of all four produce fertile offspring.



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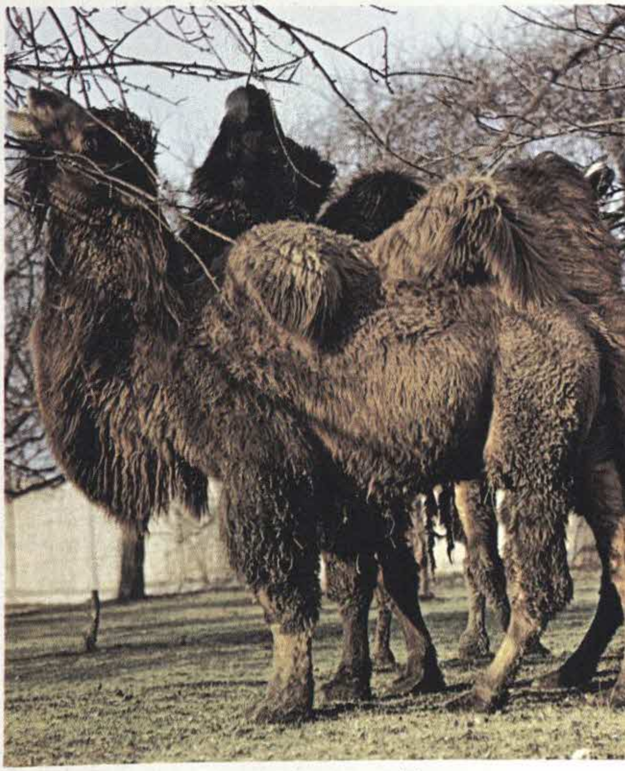


Fréderic – Jacana

There are two types of camels. Top: the dromedary is found in the Middle East and North Africa. These camels are easily identified because they have only one hump. Bottom: the Bactrian camel is the two-humped kind of camel. The Bactrian camel is found only in Asia. Fertile offspring can result from a cross of these two species of camel.

Charlie Ott, Audubon/PR

A large member of the deer family—a caribou of northern Canada. In caribou, both male and female have antlers. A closely related Eurasian species is known as the reindeer.

THE DEER FAMILY

The deer and their kin belong to the large group of even-toed ungulates, or hoofed mammals. Besides the deer family, this group inclues pigs, hippopotamuses, camels, giraffes and cattle.

About one hundred known species of deer occur widely distributed over North America, Europe, and temperate Asia. Several species inhabit South America and the Mediterranean coast of Africa. They are found in forested and mountainous areas, in brush country and swamps, on grassy plains, and on the arctic tundra.

The earliest known deer were small creatures living in the forests of Eurasia some 25,000,000 years ago. Some of the early deer had no antlers but developed tusklike canine teeth. The heads of other primitive members of the family had bony projections that were covered with skin and that were never shed. As evolution proceeded, some species of deer increased greatly in size. They included a giant moose that lived in North America something like a million years ago. The Irish elk of Europe was another huge animal. It carried a ponderous set of antlers.

GENERAL CHARACTERISTICS

The members of the modern deer family are swift-footed and have keen vision and an acute sense of smell—valuable assets to animals that are constantly hunted by carnivores. All the animals of the group are herbivores, or plant eaters. They feed upon such vegetation as grasses, twigs, leaves, and acorns, which they grind with their broad molar teeth, provided with ridged surfaces. They share with camels, giraffes, and cattle the habit of ruminating, or chewing a cud. In this process, partially digested vegetable matter—the cud—is brought back from one compartment of the stomach for prolonged chewing before it is returned for further digestion to another compartment.

The males of various species of deer grow striking antlers of bone. The females of the reindeer, or caribou also have antlers. The species that have antlers shed them every year.

The velvety growths expand, elongate, and finally branch out. The developing antlers are spongy and filled with the blood that brings nourishment needed for growth. In time the blood supply is cut off, growth ceases, and the antlers harden. The velvety skin dries and comes off in shreds. The deer, by rubbing them against tree trunks and branches, helps rid its antlers of this dead skin. Antlers serve as weapons when the males contend against one another for possession of females during the autumn mating season. In late winter or early spring, the antlers are shed. New antler growths appear very soon afterward. Red deer and caribou are known sometimes to eat their shed antlers. This seems to occur when the animals lack calcium and other mineral salts in their diet.

LIFE IN HERDS

Most species live in groups, the males normally joining the females only at breeding time. After mating, the males abandon their mates or harems to associate in herds of their own sex. Some of the animals take up a solitary existence. The females, accompanied by young, form their own herds and roam together over a fairly well defined range, the size of which usually depends upon the abundance of food. These herds are led by an older, but still reproductive, female leader. Social behavior such as this is typical with the red deer. Eight months after mating, the females give birth to one or, rarely, two white-spotted fawns. The young closely follow the parent for some time.

MANY DIFFERENT KINDS

The approximately 100 known species of deer are classified in the family Cervidae. The family is divided into seven subfamilies: the musk deer, muntjacs, true deer, water deer, American and roe deer, the moose, and reindeer or caribou.

MUSK DEER

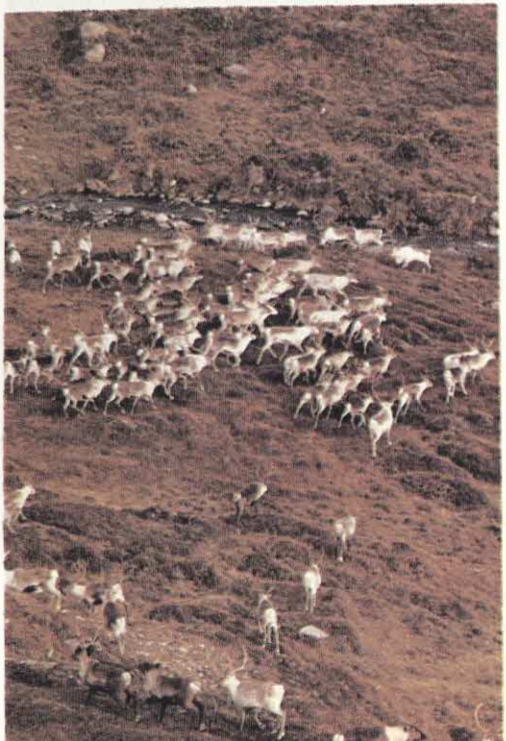
Musk deer are members of the subfamily Moschinae. There is only one genus—*Moschus*.

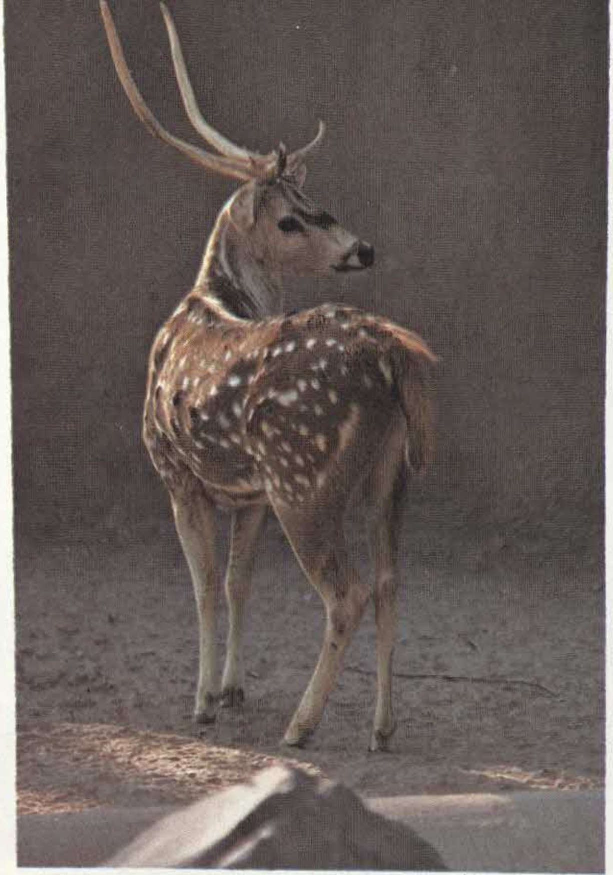
Musk deer live on wooded mountainous slopes of central and eastern Asia. They are the most primitive of living deer. The male does not carry antlers but grows, in the upper jaw, enlarged canine teeth that form curved tusks.

Musk deer stand about 50 centimeters at the shoulder. They are compact, and have thick, sturdy legs, large hoofs, long and thick hair, and a very short tail. A gland on the belly secretes on aromatic substance called *musk*, which probably serves to attract the sexes during the mating period. Except at this time, in January, male musk deer are solitary, hiding by day and feeding and moving at night. Small groups are formed by females and their young.

Deer are often found in herds that number over 100 animals. These caribou are migrating across their range in Lapland, a region in Finland where these animals are often domesticated.

Frederick Baldwin/PR





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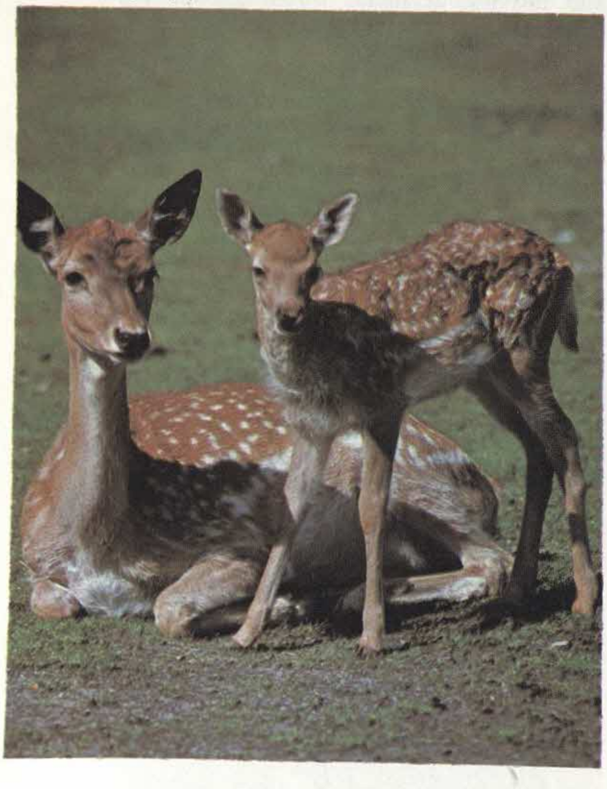


MUNTJACS

Muntjacs (genus *Muntiacus*) and tufted muntjacs (genus *Elaphodus*) make up the subfamily Muntiacinae.

Muntjacs, or barking deer, are a group of small, shy deer that inhabit forests of southeastern Asia. Males carry tusks and also short antlers, which grow from bases on the forehead. Muntjacs, and the related tufted deer, do not form groups in the wild.

TRUE DEER

The true deer of the subfamily Cervinae have longer antlers than the musk deer or muntjacs. There are four genera: fallow deer, axis deer, red deer, and Père David's deer.

Fallow deer. The small fallow deer (genus *Dama*) is striking colored in summer with orange-red brown profusely spotted with white. The male's antlers assume a palmate, or hand-shaped, structure at the top. In their native Mediterranean region, fallow deer form small bands, which hide in thickets during the day. Large herds are kept in a number of European parks.

A larger relative, the Persian fallow deer, had smaller and nonpalmate antlers. At one time, it ranged from Asia Minor to Iran. However, Persian fallow deer have not been seen in several decades and are believed to be extinct.

Axis deer. Probably the handsomest deer is the axis deer, or chital, of the genus *Axis*. This graceful, medium-sized animal sports a rich reddish coat that is vividly spotted through all seasons. Large herds roam the plains and foothills of India. Allied with the chital is the hog deer of southeastern Asia. This is a small, meager-antlered, thick-bodied creature. Chiefly nocturnal, it associates in twos or threes in grass jungles.

Red deer. Red deer, which belong to the genus *Cervus*, are found in Europe, Asia, North America, and northern Africa. They

Fallow deer and axis deer are true deer. Top: the axis deer, or chital, of Asia. It is a medium-sized deer that remains spotted throughout the year. Bottom: a small fallow deer with her calf.

prefer moorlands with running brooks or forests of deciduous trees interspersed with meadows. They are handsome animals, wearing a sleek reddish brown coat in summer, which becomes grayer during the winter. Buff-colored hairs cover the rump. Standing somewhat over one meter, the red deer is well proportioned and carries itself most gracefully. The male normally has six points, or *tines*, on each of its beautifully shaped antlers.

Red deer usually remain hidden during the day and roam in search of food at dusk. The amount of humidity seems to control herd movements. In very humid weather, the deer do not travel far. When the air is dry, they keep on the move. It is suggested that humid air favors the deer by carrying scents to a greater degree, thus allowing the deer to rely on the sense of smell for safety rather than on perpetual movement. A lone deer will rest with its back to the wind. It scans the area to the front of it and depends on its olfactory sense to tell of danger at the rear. Whenever a herd rests, one or several deer watch in all directions. With the wind blowing toward him, a person may walk to within a few hundred meters of a herd. The deer stare and uneasily stand their ground.

During most of the year, a number of stags associate in a loosely-organized band, which is not dominated by any particular group leader. The animals wander over a fairly definite home range, keeping to lower valleys and meadows during winter and ascending to higher elevations in summer. This range provides ample feeding areas and deer wallows, where the animals roll about in the mud.

Closely knit bands of females, or *hinds*, have their own separate home ranges. The lead hind controls the movements of her followers, usually consisting of her own female offspring and their calves. She is ever on the alert, watching, listening, and sniffing the air. When she senses danger, she emits a sharp, staccato bark. The group immediately stops all activity and becomes watchfully motionless until the lead hind resumes normal activity.

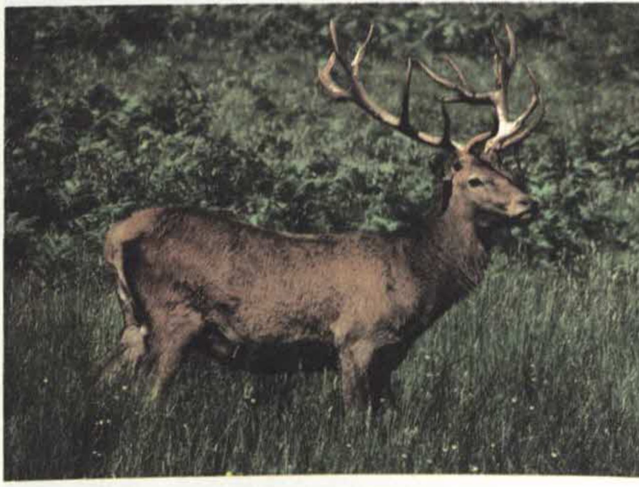
During the brief rutting, or mating, season, in September or October, stags invade the hinds' range and establish temporary harems. Each male gathers a number of females and fights for his position against contending stags. The animals vigorously push against each other with their antlers, measuring their relative strengths. Each stag dominates his harem in the sexual sphere only. If danger threatens, the hinds gather around their accustomed female leader. After mating, the males go off to their winter range. They shed their antlers in early spring.

Fawns are born in the spring. The females never wander far away from their young and return frequently to nurse them. If an enemy comes near, the fawn "freezes" on the spot. This "freezing" plus the camouflage pattern of its spotted coat is usually ample protection against predators.

The red deer of North America is the *American elk*, or *wapiti*. It is a magnificent creature with a shoulder height of 1½ meters. Generally reddish brown, it has a pale yellowish rump patch and a short white tail. Wapiti usually live in the semi-open forests and highlands of the Rockies and rain forests of northwestern North America. They move in summer to higher elevations, which are free from mosquitoes and flies, and come down into the valleys when winter snows are heavy. Browsed vegetation,

A red deer—a royal stag—of Scotland. Red deer live in separate bands of males and females. They mingle only during the mating season.

J. A. Hancock/PR



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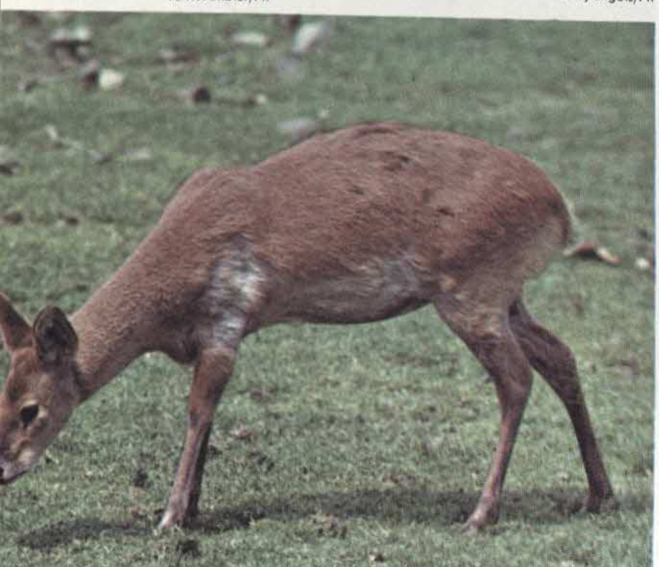


low broken tree branches, bark scraped from aspen trees, and mud wallows are signs of the wapiti's home range.

In September and October, bulls seek out cows, collecting as large a harem as they can maintain. The males announce their presence, as a challenge and threat to rival bulls, by bugling. This vibrant call begins in a low key, ascends to a high pitch, and then abruptly drops in a scream. Fights between disputing bulls are savage, though they seldom end fatally. The rivals, with necks swollen and nostrils flaring, dash headlong at one another. Though the huge spreading antlers are sharply pointed, they inflict no deep wounds because the spread of the antlers serves as a basketwork to catch the onslaughts. Usually after two or three battering assaults, the weaker bull gives up and hurriedly quits the field. Infrequently, bulls enmesh their antlers so badly that it is impossible for them to break free from one another. The animals exhaust themselves and die of starvation.

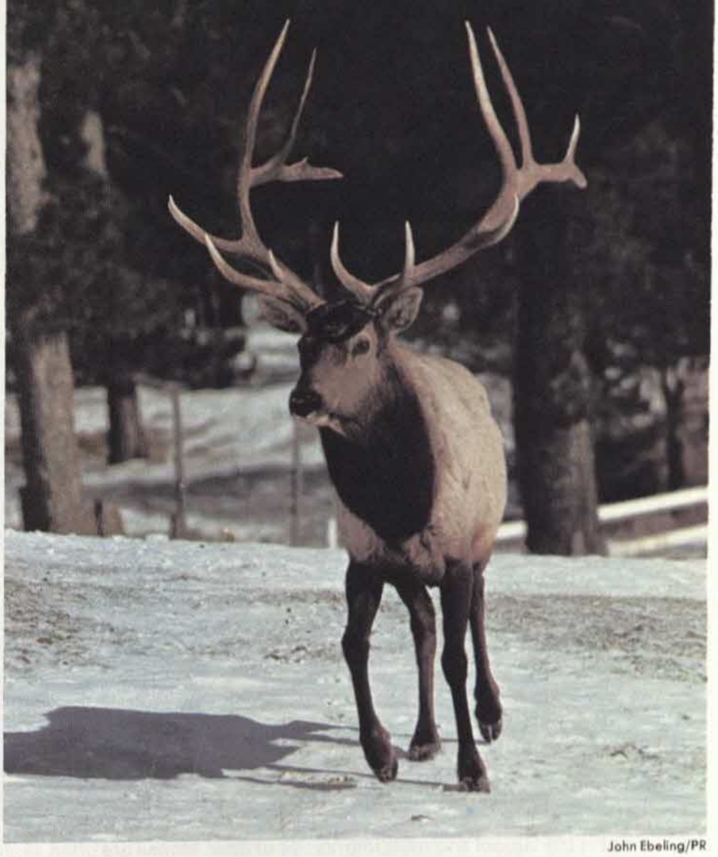
A powerful bull may gather a harem of fifty or sixty cows, but he rarely keeps it. A contending male provokes the harem master into battle. While the fight rages, other bulls split up the harem into smaller groups and each moves off with one of these groups as his own.

At calving time, in the following May or June, when one to three calves are born, the cows are alone or in twos or threes. Shortly after birth, the white-spotted calves stand and even take a few wobbly steps. As summer advances, young bulls and cows with their calves congregate in herds numbering several hundred.

Another red deer is the *sambar* of southeastern Asia and the Philippines. These large, forest-dwelling deer live singly or in small bands. The *rusa* is a small, light-brown colored sambar of Malaysia.

Other deer closely related to the red deer include: the *spotted red deer* of the

Top: the Virginia deer, a well-known white-tailed deer of North America. Middle: the mule deer, another species of white-tailed deer. Bottom: The Chinese water deer, a small deer similar to the musk deer. Water deer do not have antlers, but the males have tusklike upper canine teeth.



A male elk, or wapiti. The American elk is a very large red deer found in forests of the northwestern United States.

John Ebeling/PR

Philippines; *Thorold's deer* of western China and eastern Tibet, which has white cheeks, muzzle, lips, and chest; the Indian *barasingha*, or swamp deer, whose bright reddish summer coat is sprinkled with white; *Eld's deer*, dwelling in grassy plains and marshes in southeastern Asia; and the *sikas*, which are relatively small, spotted deer of eastern Asia, Japan, and Taiwan.

Père David's deer. The deer called Père David's deer, *Elaphurus davidianus,* is unique in that it is unknown in the wild state. During the nineteenth century a herd of these medium-sized, heavily built deer was kept by the Chinese Emperor outside Peking. Several animals were brought to Europe, and their ancestors are now bred in captivity in several parks and zoos.

WATER DEER

One genus, *Hydropotes,* makes up the subfamily called Hydropotinae—the water deer.

Water deer are similar to musk deer, the males being anterless but having tusk-like upper canines. Semiaquatic in habit, these deer frequent lowland marshes and brush country of China and Korea. Unlike other deer, female water deer bear five or six young at a time.

AMERICAN DEER

The tribe of the American deer and the tribe of the roe deer make up the subfamily Odocoileinae. The tribe of American deer, the Odocoileini, includes the white-tailed deer, the marsh deer, the pampas deer, the guemals, the brockets, and the pudus. These animals are slightly different from the red deer that we have mentioned. They are generally smaller in size, lighter in build, and have different antlers.

The *Virginia deer* is a widely known white-tailed deer of the United States and Canada. In this species the antlers sweep backward and then forward with all the tines pointing forward. These deer have large ears, and a fluffy white patch on the underside of the triangular black-topped tail. They are mostly reddish brown in the summer and grayish brown in the winter. Primarily woodlands deer, they are particularly fond of the water and feed on aquatic plants and grasses.

Leonard Lee Rue III, Audubon/PR

The moose is the largest and most impressive of deer. Moose are often seen near lakes and rivers. They are good swimmers.

The *mule deer* is also a white-tailed deer. It inhabits the west coast of the North American continent. It follows regular migration routes, spending the summer in the mountains and moving to the sheltered valleys in the fall. The mule-deer group may be distinguished by their large ears, a large white rump patch, and a short black-tipped tail. Deer of this type may stand one meter at the shoulder and reach a length of 1½ meters, excluding the 20-centimeter tail. Twin young are born in the summer about six months after mating. There are several dozen species of mule deer, each predominating in a particular area, which may be rather large. Thus the Columbia black-tailed deer ranges from British Columbia to California, the Southern mule deer inhabits the Lower California region, and the Sitka deer migrates from north of Juneau, Alaska, to British Columbia.

The *marsh deer* is found in the Amazon Basin, from the Orinoco River to the Guiana watersheds. This animal has enormous ears and large antlers. It is lustrous red in color and white on its undersides, with black legs.

The *pampas deer* dwells in the pampas and savannas of South America. It is a delicate animal with simple antlers. It is red, but the underside is white. When running, this little animal may jump as high as three meters.

The *guemals*, or *tarugas*, occur in the high Andean regions from Ecuador to Chile. They are heavy-bodied with coarse hair and a peculiar salt-and-pepper coloration. The antlers are rather simple, forming a **Y** as seen from the side, with a long main stem and a short tine over the brow.

The *brockets* also occur in the Amazon Basin. They are wholly nocturnal, as opposed to other deer, which feed at dawn and at dusk. The brockets are small and delicate and are reddish brown in color. The antlers are one-tined and straight. The tufted head is an identifying characteristic.

The *pudu* is the tiniest of all deer. It stands less than 40 centimeters high at the shoulder and is about the size of a small terrier. It lives in the temperate forest zone of the Andes and ranges all the way from Colombia to southernmost Chile. It is colored reddish brown to pale gray and its horns consist of small spikes.

ROE DEER

Among the most widespread deer groups in Eurasia is that of the roe deer. Roe deer—genus *Capreolus* of the Capreoleini tribe—are very closely related to the American deer, with which they share the subfamily Odocoileinae. Four species of roe deer are found from the British Isles to eastern Siberia and Korea. These animals stand about 70 centimeters high at the shoulder. The antlers are often knobby and start to fork near the main stem. The tail is hardly visible. In summer the roe deer are reddish brown, with an orange tone on the flanks and a white underside. In winter they are brown, with a large white rump patch.

MOOSE

The largest and perhaps most impressive of deer is the moose, or European elk. This animal belongs to the subfamily Alcinae. There is one genus—*Alces*. This magnificent beast, which stands on extremely long legs, may measure as much as two meters at the withers. The male has enormous spreading antlers. The snout is broad and rather pendulous, and a dewlap, or "bell," hangs from the throat. Moose are fond of willow thickets and forested uplands in the vicinity of lakes and rivers. They browse on leaves, buds, and bark. In summer, they consume water plants, which they get by wading or sometimes completely submerging under water. They are vigorous swimmers. Moose occur in Canada, Alaska, the United States along the Canadian border, and northern Eurasia.

During the autumn rut, bulls look for mates. They give a hoarse bellow, and a cow calls back with a softer, somewhat longer bellow. If another bull is near, the two fight fiercely for possession of the female. The victorious male remains with the female for several days and then searches for another cow.

Usually two unspotted calves are born the following May. They nurse for some time and may follow the cow until just before next year's calving when the cow drives away her yearlings. Females and their calves go to high ground in the summer and descend to lower country as winter approaches. In winter, several moose may associate. They tramp down the snow in a sizable area, called a *yard*.

The powerful bull moose, using antlers and forefeet, can kill a full-grown bear. Man is practically the moose's only enemy.

CARIBOU

About one hundred years ago caribou, members of the subfamily Rangiferinae, abounded in the northern United States and Canada. Today they are numerous only in the Canadian Rockies and the Barren Grounds of northern Canada. In the caribou both sexes are provided with antlers. The main stems of the antlers sweep back and up from the head, spreading as they rise, then bending forward and ending in a flattened palm. The animal is large. It may stand nearly two meters high at the shoulder. The nose is generally covered with hair and there is a pronounced dewlap at the throat. The hoofs are broad and the two cloven sections are spread wide apart. Dewclaws, hoof vestiges, are attached to them. The caribou subsists mainly on mosses. The fast, steady trot of the animal protects it from one of its enemies, the wolf. Man is its greatest enemy, for the flesh of the caribou forms the main staple of the diets of Eskimos and northern Indians.

There are various caribou species. The Greenland caribou is a small, light-colored animal with slender antlers. The dwarf caribou is darker and heavier than the Barren Grounds caribou. Its antlers are stouter and less flattened. It roams the evergreen coniferous forests of the northeastern United States into Canada from the Great Slave Lake to Newfoundland. In the Eurasian arctic region, a species of caribou—*Rangifer tarandus*—known as the *reindeer* has been domesticated. It has long been used by the Lapps for food, clothing, transportation, and many other things.

The giraffe is the tallest of the land mammals. It has an unusual style of running, but it is very speedy—a good defense against predators.

Donald Paterson, Coleman & Howard/PR

GIRAFFES

The giraffe is the tallest of all living land animals. It can grow to a height of nearly six meters. The animal is somewhat unusual-looking; its body seems to go straight up and down.

Giraffes are long-necked, long-legged, spotted animals. The ancient Egyptians thought the giraffe was the offspring of a camel and a leopard. This idea is reflected in the scientific name of the common, or steppe, giraffe—*Giraffa camelopardalis*.

Giraffes are classified in two genera of the family Giraffidae: the steppe giraffes, *Giraffa*, and the forest giraffes, or okapis, *Okapia*.

THE STEPPE GIRAFFE

Today steppe giraffes are found in the wild only in Africa south of the Sahara. Fossil evidence indicates that they were once more widespread, roaming over Europe and Asia as well as most of Africa.

The giraffe's forelegs are longer than the hind legs. Hence, the neck is thrust upward instead of forward, sloping the back downward from head to tail. The neck itself, though it has the normal number of seven vertebrae characteristic of most mammals, is enormously elongated, reaching nearly two meters in length. The head can be placed on a line with the neck, so as to extend the reach still farther. The tongue, too, can be thrust out to an amazing extent.

The giraffe is one of the most specialized of animals. If the tree foliage on which it feeds were ever to become scarce, the animal would be hard pressed for food. Ground-feeding and drinking water are difficult maneuvers for the giraffe. It must straddle wide with its front legs in order to bring its mouth in contact with the earth. On the other hand, with its great reach and its flexible, prehensile lips and tongue, the animal can readily pluck the leaves of trees when feeding.

It has often been said that the giraffe is mute because it has no vocal cords. But giraffes do utter sounds. They groan when they are injured. The females call to their young when they wander off.

Zoologists have long been puzzled by the giraffes' fantastic ability to withstand thirst. In some arid regions, as far as we know, they cannot find water for seven or eight months of the year. The desert animals may, of course, know of water sources of which men are ignorant.

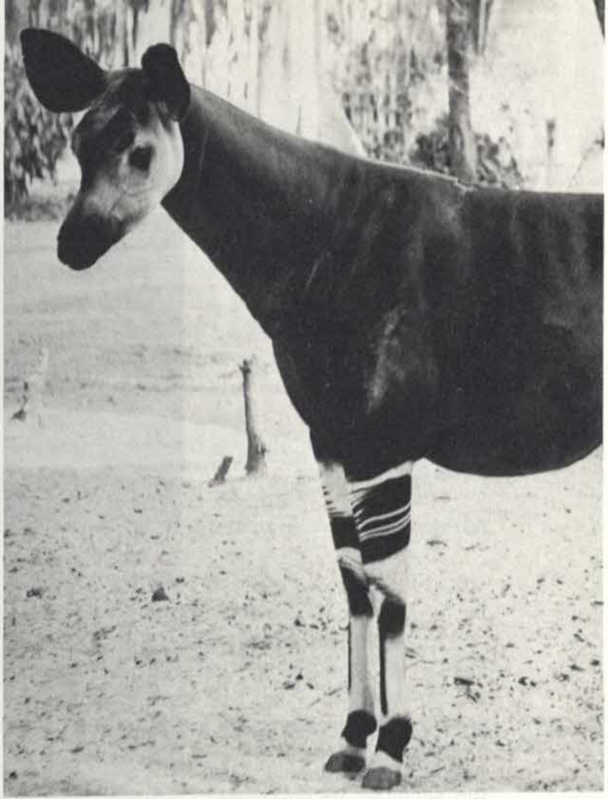
The giraffe travels in herds generally made up of a full-grown male and several females with calves. Larger herds are made up of males and females of various ages.

The giraffe is quite friendly in tourist areas. The horns, present in both males and females, are useless as weapons since they are covered with soft fur. However, the animal can deliver a powerful blow with its feet or its head. It has been known to kill big-cat predators by smashing in their chests with its powerful hind legs.

FOREST GIRAFFES – OKAPIS

A comparatively short-necked relative of the giraffe is the okapi, *Okapia johnstoni*. The okapi is the only species of forest giraffes.

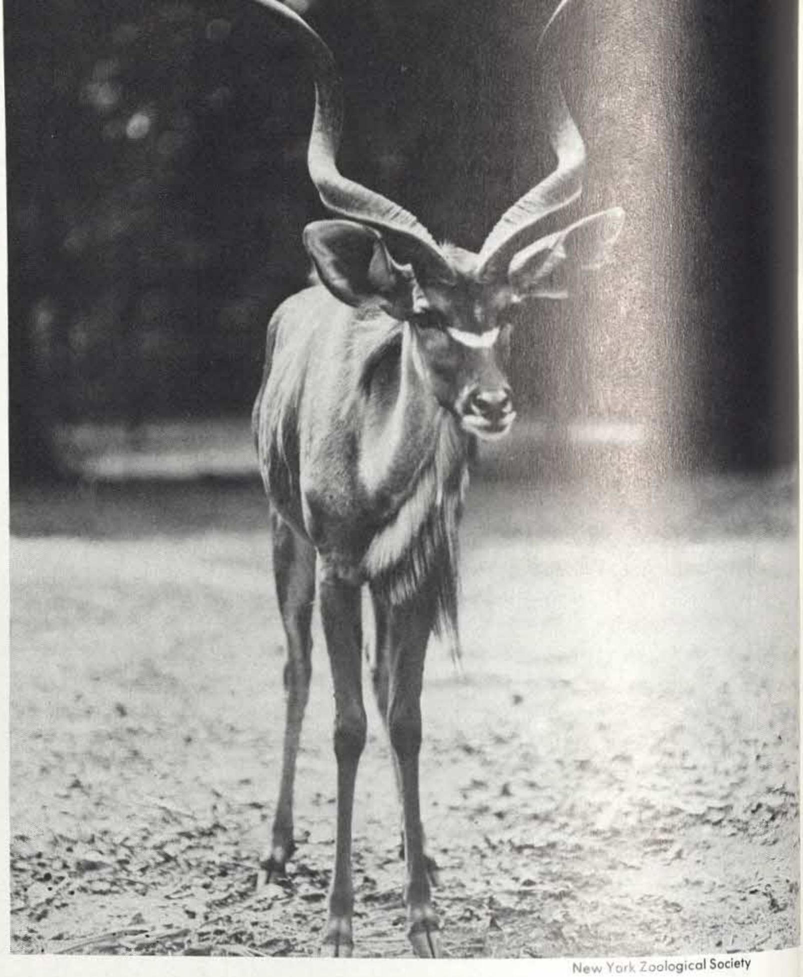
The okapi is found in the upper Congo region in Africa. The male stands a little over 1½ meters at the shoulder. It has a compact body light brown or dark gray with light stripes on the belly and legs. Only the males have horns.



Ace Williams/PR

Grant Heilman

Top: The okapi, or forest giraffe, a seldom seen short-necked relative of the familiar steppe giraffe. Bottom: a baby giraffe with its parents. Only one young is usually born, and it is able to run soon after birth.



Male of the greater kudu. This stately antelope stands about 150 centimeters at the shoulder. Its corkscrew horns may be over 120 centimeters long.

New York Zoological Society

THE ANTELOPE FAMILY

Antelopes are vegetation-eating hoofed mammals. They are closely related to cattle, sheep, and goats and are classified with them in the family Bovidae. In fact, the name "antelope" is generally given to any species of the family Bovidae that is obviously not a sheep, goat, or a member of the cattle group.

Most antelopes are quick-moving creatures with highly developed senses of sight, smell, and hearing. They are generally slender and graceful and yet surprisingly sturdy. Many of them, such as bongos and kudus, have beautiful markings. In size these animals range from the dainty little royal antelope, which is only about 25 centimeters in height, to the giant eland, measuring nearly two meters at the shoulder.

Like all the members of the Bovidae family, the antelopes are ruminants, or cud-chewing animals. Like the rest of the Bovidae, too, they have unbranched, hollow horns which, sheathlike, fit over bony cores projecting from the top of the skull. These horns are permanently attached and thus differ from deer's antlers, which are shed annually. Antelope horns are of different sizes and shapes. Some are spiral or lyre-shaped; some curve backward; still others are short and straight.

EVOLUTION

The early ancestors of our modern antelopes were small, hornless creatures, which lived in Eurasia about 30,000,000 years ago. Their forelegs were much shorter than their hind limbs. The front teeth, or incisors, of the upper jaw were greatly reduced or entirely absent, while the canine teeth were only moderately developed. In the course of time, small and relatively straight horns appeared; the canines were lost; and high-crowned molar teeth were developed. These enabled the animals to grind grasses more effectively.

From these early grazers arose many kinds of antelopes, such as the oryx, the klipspringer, and the gazelle. About 6 million years ago, there appeared the cowlike antelopes—the eland, the nilgai, the gnu, and the hartebeest. Our modern cattle developed from types such as these.

During the period when ice covered much of the Northern Hemisphere, many of the Bovidae sought refuge in southern Asia and Africa. Today the true antelopes are restricted to those two continents. Of the animals closely related to them, only the bison, mountain sheep, mountain goat, and musk ox established themselves in the New World.

MANY DIFFERENT KINDS

There are a large number of antelopes. They are classified in four subfamilies. The Bovinae, in addition to the cattle, include the handsome, large African antelopes that have spiral horns. Members of this group are the eland, bongo, kudu, and bushbuck, as well as the nilgais from India.

A second subfamily of antelopes is the Hippotraginae, which include the large horselike antelopes such as the addaxes, oryxes, and roan, blue, and sable antelopes, as well as the odd-looking hartebeests and gnus, or wildebeests. The subfamily also includes the water-loving antelopes: waterbucks, kobs, lechwes, reedbucks, and rheboks.

The small African antelopes known as duikers make up their own subfamily, the Cephalophinae.

The gazelles and impalas are members of the subfamily Antilopinae. Also included in this group are blackbucks, springboks, dibatags, and gerenuks, as well as the dwarf antelopes—the dik-diks, klipspringers, steinboks, and royal antelopes.

SPIRAL-HORNED ANTELOPES

The large African *eland* is similar to an ox in build. Belying its size, however, it is an agile, fleet-footed animal. Like some wild cattle, it has a dewlap, or flap of skin, under the neck. Its long horns, though spirally twisted, are straight.

Elands live in partially wooded, partially open country. To get at leaves and twigs, they sometimes break off small trees by wedging the trunk between their horns and twisting their head.

The secretive *bongo* frequents dense bamboo forests, where it relies on its keen hearing to escape enemies. It is colored a chestnut red, striped with white along the sides of its body.

The handsome greater *kudu* is at home in dense thickets of the hill country or in tangled scrub and thorn of lower levels. When pursued, these antelopes flee to the highest and roughest part of their range. The kudu may be found from Cape Province in the south to Ethiopia and Somalia in East Africa. The lesser kudu, short-horned and standing about 100 centimeters at the shoulder, is confined to east Africa, from Ethiopia to Tanzania. It possesses white patches on its throat and chest and lacks the long throat mane that is displayed by the greater kudu.

The *nilgai* of India is an Asian relative of the African harnessed antelopes. This

A female eland and her calf. Elands are large animals with straight horns and a dewlap, or flap of skin, hanging under the neck.

Lincoln Park Zoo

large and rather awkward creature, with stubby, crescent-shaped horns, once roamed over a far wider area than it does now. The male, or bull, antelope is slate blue in color; that accounts for the name nilgai, which means "blue bull." It may measure up to 140 centimeters in height.

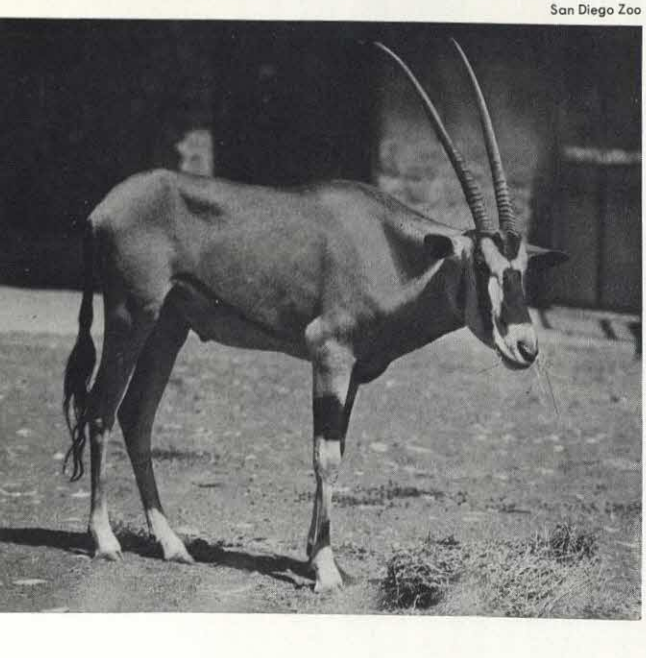
The little *chousingha,* or four-horned antelope, is another native of India. This species is unique among antelopes, for the males wear two pairs of short, spiky horns, one behind the other. The fore pair is about five or six centimeters long, while the hind pair may measure 12 centimeters. The body of the chousingha is about one meter in length, and the animal stands 60 centimeters at the shoulder. Its coat is red-brown with white-streaked underparts. It frequents the wooded and hilly country of peninsular India, away from the jungles.

ADDAXES, ORYXES, AND THEIR RELATIVES

Another important antelope subfamily includes the addax, roan, and sable antelopes and the oryx. These are large-sized beasts, with long, tufted tails, neck manes, and striped faces. The horns, borne by both sexes, are either spirally twisted, curved backward, or long and straight. They are all native to Africa except the Arabian oryx, which ranges from Saudi Arabia to Iraq.

The beisa oryx of northeastern Africa. When it is seen from the side, its profile resembles that of the mythical unicorn.

San Diego Zoo



The *addax* dwells in the desert regions of northern Africa. Its coat is a yellowish white, and it has a patch of black hair on the forehead. The horns of both sexes are ringed, and they form open spirals.

The *roan antelope* is found south of the Sahara as far as the Orange River in southern Africa. It reaches a shoulder height of one and one-half meters or more. The coat is red-brown, and the belly is white. The curving horns of the roan may be as long as one meter.

Another species, *the blue antelope* of southern Africa, was hunted to extermination in the early part of the twentieth century. This antelope, resembling the roan antelope, was a blue-gray in color.

The *sable antelope* of central and east Africa is a handsome black animal that has splendid scimitar-shaped horns. At shoulder height the male sable stands nearly one and one-half meters tall. The coat is black-brown to glossy black, with a white understreak.

The pale *Arabian oryx* has long, straight horns, while the *white oryx* of northern Africa bears horns that curve backward in a wide sweep.

The *gemsbok* is another oryx, dwelling in the deserts of southwestern Africa. It is a big antelope with a pair of straight, slender horns measuring more than one meter in length. The neck, back, and flanks are a pale red-gray, while the belly is white and the head white, marked with black. The tufted tail is black.

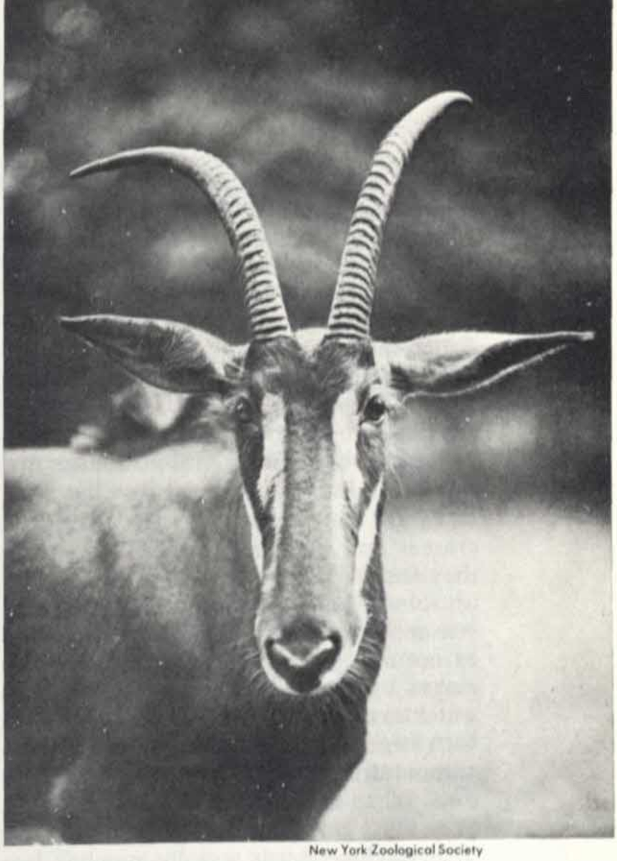
The horns of the *beisa oryx,* of northeastern Africa, are very formidable. Though in medieval times it was the long tusk of the narwhal that was displayed as the horn of the mythical unicorn, it is thought that a glimpse of the beisa may have inspired a poetic conception of the appearance of that one-horned creature.

The body shape of the beisa calls to mind the form traditionally assigned to the unicorn. Though the beisa obviously has two horns, the animal, if seen from the side, would present a silhouette suggesting a beast with one horn jutting from the middle of its forehead.

SURVIVING IN OPEN LANDS

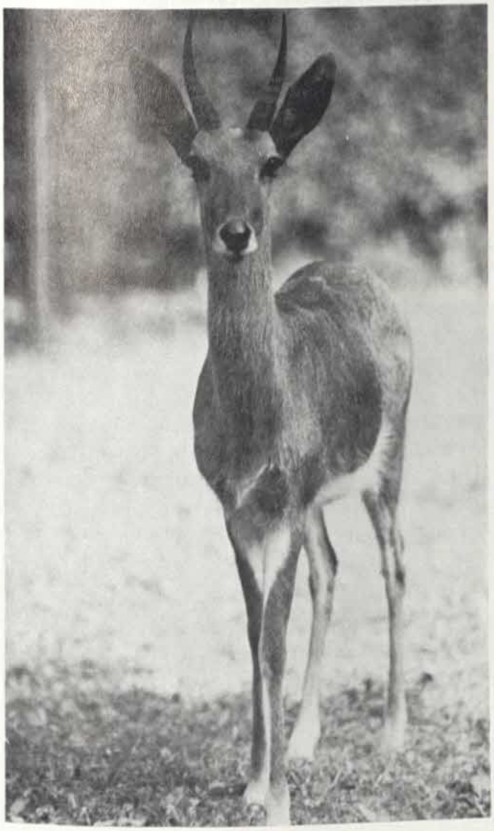
The big antelopes that we have just described—the addax, roan, sable, and oryx—look a great deal like thoroughbred horses. Certainly their gait when walking, running, or galloping is quite horselike. The magnificent, high-stepping sable antelope, with its mane flying, neck arched, and chin drawn down, resembles a spirited, coal-black horse. The hoofs of the sable, roan, and oryx are large, supporting the powerful and well-formed legs. The addax's hoofs are especially large, an adaptation that makes it easy for the animal to walk and run on desert sand.

Since all of these antelopes live in fairly open grasslands and deserts, they must be very fast to escape from such predators as lions and wild dogs. The roan antelope can attain a speed of 50 to 60 kilometers per hour, and probably the others of this group can run as swiftly. If the antelopes are cornered or wounded, they will fight courageously. With quick and powerful thrusts of their sharply pointed horns they can often hold their foes at bay. African natives occasionally come upon the remains of sable and lion lying together, the lion impaled upon the horns of the sable.



New York Zoological Society

The large sable antelope is native to Africa. The male sable antelope is about 140 centimeters at the shoulder. This antelope arches its neck when it runs.



New York Zoological Society

Left: the mountain reedbuck. Only the male of this medium-sized antelope has horns.

Living in open country as they do, these antelopes congregate in small herds, probably because a number of individuals have a better chance of survival than a single individual or a pair. For one thing, if one or several members of a scattered herd find food, the others of the group will be attracted to the food supply by the feeding actions of the original discoverers. Approaching predators have a good chance of being spotted by several individuals of the group. Their reactions will give warning to the rest. If attack comes, the herd's concerted defensive action may discourage the enemy.

The grassland and desert homes of these antelopes are devoid of heavy rainfall during the greater part of the year. Consequently, the animals are adapted to survive without drinking water. Occasionally water can be had by lapping up dew from grasses or trickles of rain water from foliage and tree bark. But for the most part the antelopes get the water they need from the grasses and succulent plants upon which they feed. Possibly, the animals also burn up some of their stored fat during the dry season. This fat, on being consumed, releases not only energy but water, too, which makes up for at least part of the body's water needs. It is truly remarkable that such large herbivores as these can get along without drinking water for great lengths of time. When the water holes are filled, however, these antelopes drink regularly.

Antelope herds usually number less than a hundred members. The smallest groups are formed by those species living in deserts where food is not abundant. Often one or several large bulls assume herd leadership. A herd of sable antelopes, containing ten to eighty individuals, for example, is led by a single adult bull, which has to defend its position against all adult males vying for leadership. The unsuccessful males remain separate from the main herd and form a bachelor band of their own. During the breeding season, the herds of some antelope species break up, with males and females forming pairs. The young calves and their mothers often remain away from the group for a month or two.

HARTEBEESTS AND GNUS

The hartebeests and gnus, or wildebeests, are antelopes built for speed and endurance. These African antelopes live in large herds on open grasslands. Some species of hartebeests frequent arid regions where they can live almost entirely without water. The gnus depend upon sources of water and migrate long distances.

Relying on speed to escape enemies, the hartebeests can run for some distance at 65 kilometers per hour. The gnu is even faster, making 80 kilometers per hour. When excited or stampeded, the gnu prances about and leaps in the air. Then it tosses its head, kicks its heels, and swishes its tail as it breaks into a fast trot, which soon changes to a gallop.

Hartebeests and gnus are large animals, standing high at the shoulders. The back slopes downward to the haunches. The tail is long and bushy, similar to a horse's tail. Both males and females carry horns.

Hartebeests have long, slender muzzles. Their horns are ringed and form a **V** or **U** when seen from the front. The upper end of each horn bends rearward. The gnu's muzzle is long and broad. Tufts of hair stud the face, and a stiff mane fringes the neck. The horns are smooth, have a widened base, and curve first downward and then upward.

WATER-LOVING ANTELOPES

The waterbuck, lechwe, kob, reedbuck, and Vaal rhebok are closely related antelopes never found far from water.

The waterbuck is large, while the others are medium-sized. Only the males have horns, which are moderately slender, ridged, and bent in gentle curves.

Waterbucks and *kobs* graze on partially wooded grasslands, but take to water if danger threatens. Waterbuck males gather harems of females. After the mating season, during which males fight for mates, several waterbuck families commonly dwell together. Male and female kobs mix in herds, except at breeding time, when each male gathers several familes into a temporary harem.

The *Vaal rhebok* prefers hilly country, keeping to open mountain slopes by day and coming down onto the plains to graze and drink at night. Vaal rheboks live in family groups of several females and fawns led by an adult male.

The *reedbuck* frequents dense reed beds but when frightened seeks refuge in a dry, bushy area. Reedbucks are solitary antelopes. Only a female and her fawn are bound together for any length of time.

The *lechwe* often enters swamps up to

its belly to feed on aquatic vegetation. It swims strongly when pursued.

DUIKERS

Duikers, or duikerboks, form a subfamily of small or medium-sized antelopes living in Africa south of the Sahara. Some duikers inhabit the tropical rain forests. The others are at home in bushy country, where they take cover in the dense thickets.

The horns of the male duikers are short spikes. The females of most species also have horns.

Duikers apparently associate in pairs. Mating takes place in the month of October, and one or two young are born the following April or May.

DWARF ANTELOPES

Another subfamily includes the oribi, klipspringer, steinbok, grysbok, royal antelope, suni, and dik-dik. These African antelopes are, for the most part, small, delicately built creatures standing under two-thirds of a meter. The oribi is a little larger, and the dik-dik, suni, and royal antelope are rabbit size. The horns, usually worn only by males, are small and spikelike. Generally these antelopes associate in pairs or are solitary.

The *klipspringer* inhabits rocky regions. It leaps agilely and scales steeply inclined rock faces. Its narrow, high hoofs give it a firm grip on smooth surfaces.

The *royal antelope* and *suni* are forest dwellers, while the *dik-dik* prefers bush country, where it dashes through the undergrowth like a frightened hare.

Steinboks and *grysboks* are found in bushy areas and open plains. The *oribi* lives in the foothills and plains, hiding in tall grasses and dense thickets. Oribi pairs mark their home territory by smearing the secretions of special facial glands on certain trees and bushes.

THE GAZELLES

The fleet-footed gazelles and their allies—the gerenuk, dibatag, impala, blackbuck, and springbok—are attractive and graceful animals of medium size. Many live on semiarid plains or deserts. The impala prefers openly wooded, grassy country.

Gazelles are found widely distributed in Africa and southern Asia. The handsome *blackbuck,* which has long horns spirally curved like a corkscrew, inhabits India.

The *gerenuk* is a slender gazelle with an exceedingly long neck and elongated legs. It often stands on its hind legs to browse on leaves. The *dibatag* is another long-legged and long-necked gazelle.

Springboks and *impalas* can make long, high leaps. The springbok has white hairs on its back. Whenever it is alarmed, the animal erects these hairs.

A female impala and young running through African grasslands. Impalas are medium-sized graceful, fleet-footed members of the antelope family.

New York Zoological Society

Generally speaking, lemurs and their relatives are small mammals with thick or woolly hair and quite large eyes. Some have long, bushy tails; others, ratlike tails; a few, only a stub. All lemurs grip powerfully with their hands and feet, and they fight more with their hands than with their teeth. They utter grunts, clucking sounds, and piercing cries. They are almost completely arboreal. They eat insects, fruits, birds, and eggs.

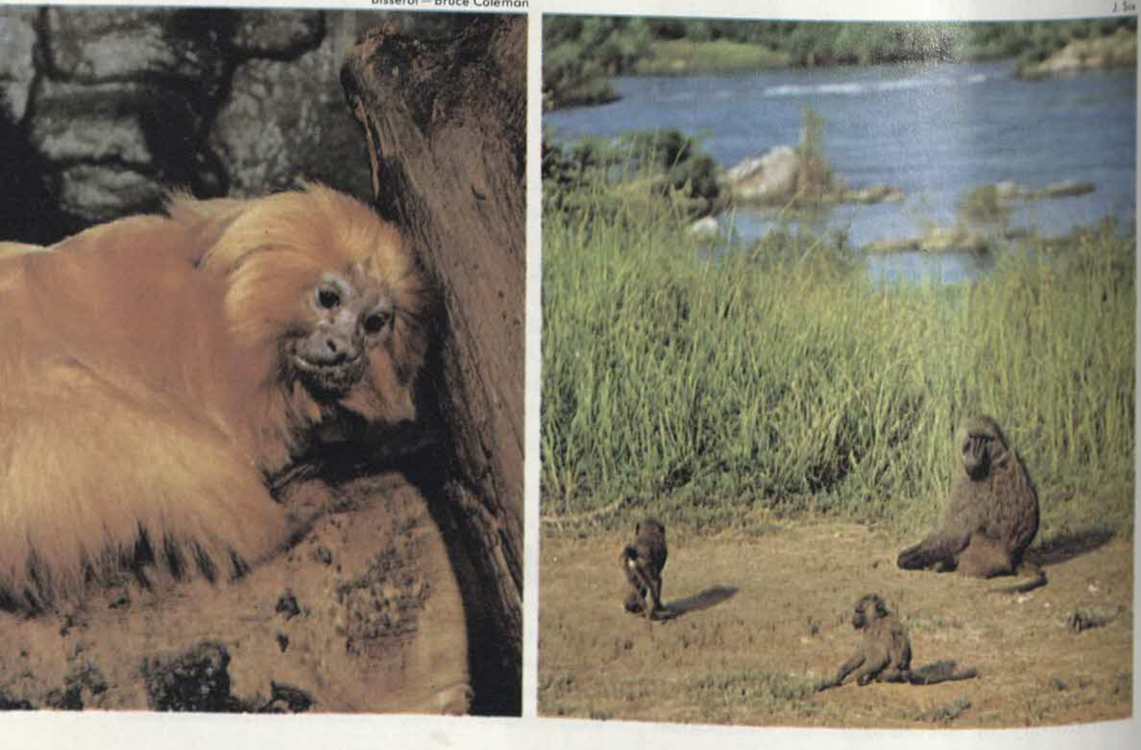
The lemurs are inhabitants of Madagascar and several nearby islands. There are many different varieties. Perhaps the most peculiar of all is the aye-aye *(Daubentonia)*, which has rodentlike front teeth and long thin fingers, bearing claws. The third finger is especially thin, suggesting a wire. It is used to probe for grubs. The aye-aye has big eyes, large ears and a keen sense of hearing. The indri *(Indri)* is the largest lemur. It has partially webbed toes and a stubby tail. A near relative is the sifaka *(Propithecus)*, with a long tail. A membrane of loose skin between upper arm and armpit is used for gliding.

GALAGOS, LORISES, AND POTTOS

The lemurlike primates known as the galagos, lorises, and pottos live in Africa and Asia. The small galagos *(Galago)*, or bush babies, have long tails and elongated feet specialized for hopping and jumping. They inhabit the African forests and grassland country. They usually congregate in family groups, sleeping together during the day and hunting for insects during the night. The galago moistens its palms and soles with a drop or two or urine when it finds climbing a bit difficult.

Lorises are almost tailless primates with stubby index fingers and shorter muzzles than most lemurs. The slow loris *(Nycticebus)* is a heavily built animal, and moves most deliberately. It is a native of

Left: a maned marmoset. Marmosets and their close relatives, the tamarins, live in South America. Right: a female baboon and her young. Baboons live in organized troops.



Bisserot—Bruce Coleman

J. Six

Southeast Asia and Indonesia. The slender loris (*Loris*) of India and Sri Lanka is smaller and lighter. Like the slow loris, it hunts at night among trees and bushes for fruit and sleeping birds. The slender loris rests by day with its body rolled into a ball, hands grasping a tree bough, and head tucked between the legs.

The African pottos (*Perodicticus*) resemble lorises. They have the typical rudimentary tail and index finger. The spines of a potto's neck bones protrude noticeably. When the animal bends its neck, these spines look like a row of pegs pushing up beneath the skin.

TARSIERS

The tiny tarsier (*Tarsius*) has big eyes, large ears, long hind legs, and a long, naked tail, which is tufted at the tip. It moves in long leaps, somewhat like those of a frog, through the branches of trees as it hunts insects at night. The tarsier dwells in the forests of the Philippines, Celebes, Sumatra, and Borneo.

HIGHER PRIMATES

Apes and monkeys are separated by a fairly wide gulf from the lower primates—tarsiers, lemurs, and lemurlike animals. Not only do the higher primates differ in outward appearance from their more primitive relatives, but they display a greater awareness of the world about them. The ape or monkey is driven by curiosity. It thoroughly investigates every object, picking it up, smelling it, tasting it, manipulating it, and experimenting with it. By examining objects and exploring situations it becomes aware of its complex environment and is able to live successfully wherever it finds itself. The lower primates lack this searching curiosity and this ability to adapt themselves to a strange environment. They are more specialized animals in their habits and their food requirements and are found in more restricted habitats.

NEW WORLD MONKEYS

The New World monkeys are medium-sized and small primates, living in the forests of Central and South America from southern Mexico to northern Argentina. These monkeys differ in certain important respects from their Old World relatives. The most noticeable distinction is the wide separation between the nostrils, which open to the sides of the nose instead of to the front and downward. They lack cheek pouches and so-called *ischial callosities*, or rough skin pads on their hindquarters. Most New World monkeys have long tails. In some cases, the tail is *prehensile*—that is, it is used for grasping.

Comprising one group (family Cebidae) of New World monkeys are the spider and woolly spider monkeys, woolly monkeys, howlers, capuchins, saimiris, sakis, uakaris, titis, and douroucoulis. The second

Macaques occur widely from Japan, Indonesia, Southeast Asia, and India to northern Africa. The best-known macaque is the rhesus monkey.

Charles Lenars

Lavaud—Ziolo

Macaques are very hardy animals, which accounts for their wide range. This Japanese painting shows a macaque living near snow-covered mountains.

group (family Callithricidae) is made up of the marmosets and tamarins.

Spider monkeys. The spider monkey *(Ateles)* is a tree dweller with a wonderful prehensile tail, which acts as a third hand for grabbing limbs or fruits and nuts. This monkey swings by its exceedingly long arms, hooking onto branches with its thumbless hands. Sometimes it leaps outward and downward, with arms and legs spread, covering five to ten meters. It may drop straight down to a branch five to seven meters below. The related woolly spider monkey *(Brachyteles)* has woolly gray hair, a naked red face, and a more heavily proportioned body. Closely allied to the spider monkeys are the woolly monkeys *(Lagothrix)*, which have thick, woolly coats, heavy large bodies, and well-developed thumbs. Though prehensile, the tail apparently does not grasp as well as the spider monkey's tail.

Howler monkeys. Howler monkeys *(Alouatta)*, the largest New World monkeys, are aptly named, for their roars are almost deafening. These disconcerting sounds are produced by air passing through a resonating chamber in the throat. The howlers are powerfully built animals: they have high foreheads, projecting muzzles, and bearded chins. They prefer to remain in high trees. They swing on vines to span the gaps between trees and jump only when necessary. The howler's prehensile tail serves various purposes. The animal hangs by it, uses it as an "anchor" when resting or sleeping, and scratches otherwise inaccessible spots on its body with it.

Capuchin monkeys. The tails of capuchins *(Cebus)* are also prehensile, but are not so versatile. Capuchins range from Mexico to Paraguay. They have woolly coats of coarse or silky hair. The name comes from a peak of thick hair, resembling a monk's hood, on the top of the head of the capuchin.

Marmosets and tamarins. Marmosets *(Callithrix)* and tamarins *(Leontocebus)* are the smallest of all monkeys. The pygmy marmoset measures only 30 centimeters, one half of which is tail. Some marmosets have long thick hair, manes on the head and shoulders, or hair tufts on the ears. The tails are long, nonprehensile, and marked by rings. Tamarins have longer hands than the common marmosets, but lack ear tufts and tail rings. Both marmosets and tamarins look and climb like squirrels. The fingers and toes, except the big toe, have hooked claws instead of nails. Since the thumb is not opposable to the other fingers, these monkeys must climb by digging in with the claws instead of grasping boughs as do other monkeys.

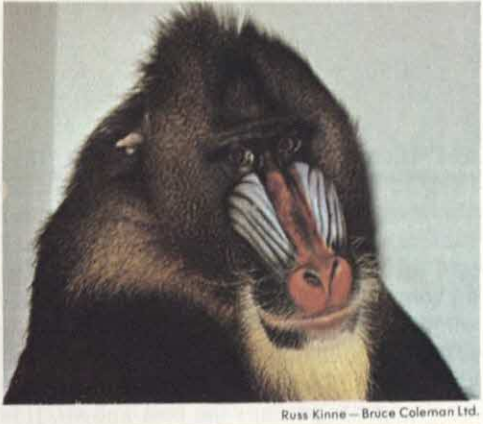
OLD WORLD MONKEYS

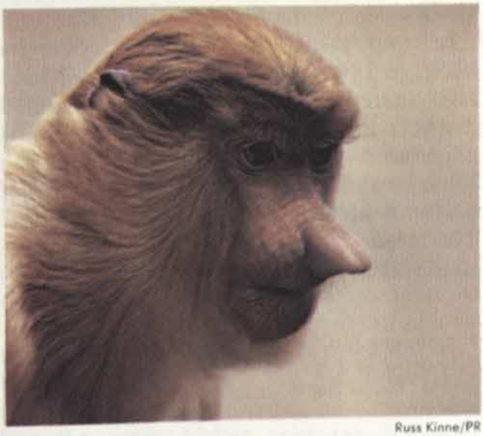
There are several hundred species of Old World monkeys (family Cercopithecidae), which range widely over Africa, southern and eastern Asia, and the islands of the Far East. The majority of these monkeys prefer warm climates. Some species, however, find sufficient vegetation for shelter and food at elevations and latitudes where snow commonly occurs.

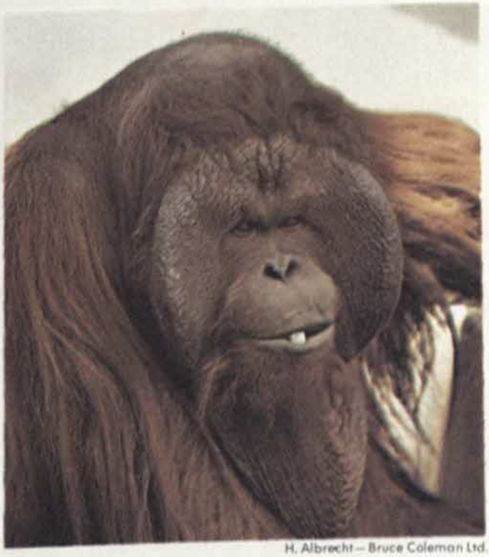
The Old World monkeys travel through the trees by running along the boughs and leaping, rather than by swinging by the arms. They walk or run on all fours, flat on the palms of their hands and the soles of their feet. Their shoulders are narrow. Their arms are usually shorter than their legs. Their chests are deeper than they are wide. Their coats show striking greens, reds, and blues, and the areas of skin on the face, chest, and limbs are brilliantly pigmented. The Old World monkeys have prominent ischial callosities, which are often surrounded by naked, colored skin. Though some of these monkeys have very long tails, others have mere stubs or no tails at all. None can use their tails for grasping. The nostrils are set close together, opening forward and downward. Like the apes, the Old World monkeys tend to assume an upright posture when sitting. Vegetable matter, fruits, eggs, lizards, and insects make up their diet.

The Old World monkeys are divided into two subfamilies. The first group (subfamily Colobinae) includes the langurs, snub-nosed monkeys, and proboscis monkeys of Asia, and the guerezas, or colobus monkeys, of tropical Africa. These animals are long-tailed, medium-sized, and fairly slender. They are mainly vegetarians and possess a complicated stomach, divided into several compartments. They lack cheek pouches. In the second group (subfamily Cercopithecinae) are found the Asian macaques and the African mangabeys, baboons, mandrills, guenons, and patas monkeys. They have cheek pouches and a simple stomach.

Langurs. Langurs *(Presbytis),* or leaf monkeys, are common in India, Sri Lanka,


Russ Kinne—Bruce Coleman Ltd.


Russ Kinne/PR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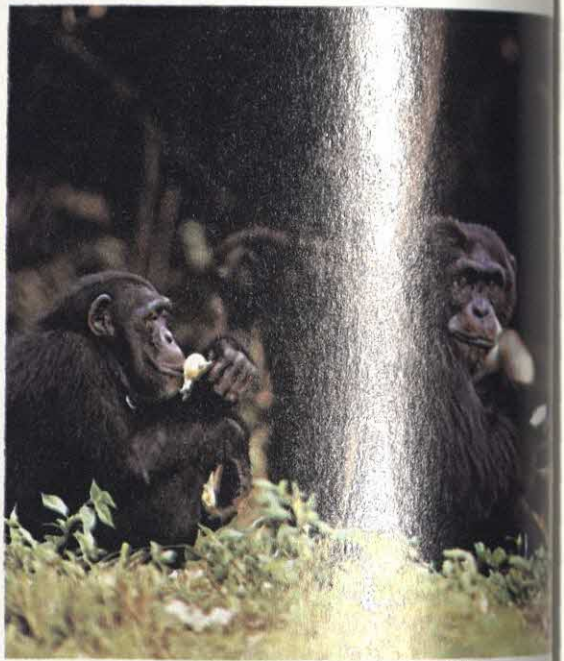
Three species of primates, showing the differences in the structure of the face. Top: the mandrill, which is easily recognized by its brightly colored face, has a prominent snout. Middle: the proboscis monkey has a moveable snout so long that it hangs down over the mouth. Bottom: the orangutan's face is flattened, but the jaws are still heavy and prominent.

and Indonesia. For the most part they keep to high trees, where their long tails serve as balancers when they leap through the branches. Their coats range from black and brown through red to gray and white. In some species there is a high crest of hair on the top of the head. Stiff hairs grow forward above the eyes.

Among these lithe monkeys, the hanuman langur is perhaps the best known. It is silvery coated, has black hands, feet, and face, and carries its tail arched over its back, in squirrel fashion. The hanuman is held sacred by the Hindus. In populated districts it is very common and quite mischievous. A closely allied monkey, the Himalayan langur, lives in the mountains of Kashmir at an elevation of 1,800 meters. The large pig-tailed langur, dwelling on the small islands off Sumatra, has a short upturned nose and a short, almost naked tail. The snub-nosed monkeys *(Rhinopithecus)* of Tibet and western China are more stoutly built than the true langurs, and their noses are turned up sharply at the tip.

A mountain gorilla of central Africa. Male gorillas may grow to 2 meters and weigh up to 250 kilograms. Males begin to turn gray after they reach maturity.

G. Hotton/PR



N. Tomalin – Bruce Coleman

The chimpanzee is a very intelligent primate. Even in the wild it manufactures and uses tools.

Proboscis monkey. The most eccentric of all monkey noses is that of the male proboscis monkey *(Nasalis)*. It is a swollen, movable snout, with the tip drooping over the mouth. This grotesque appendage seems to affect the voice, which is decidely nasal. Females and young have snub noses. The proboscis monkey is chestnut colored. Its reddish brown face is set off by side whiskers and a beard. It lives near streams and rivers in the forests of Borneo and is a capable swimmer.

Guerezas. The handsome guerezas *(Colobus)* live in the forests of tropical Africa. Some are auburn or carrot colored. Others are black, with long white hairs forming a mantle on the shoulders or sides and fringing the tail. Some have beards. The thumb of all the guerezas has been so reduced that it forms only a little stub. Because of their ornamental costume, these monkeys have been a prey to fur hunters.

Macaques. Macaque monkeys *(Macaca)* occur widely from Japan, Indonesia, and southeast Asia through India to northern Africa. They are extremely hardy, thriving in tropical jungles and snow-covered mountain slopes. They are stout, medium-sized animals with short, stocky limbs, a projecting but rounded muzzle, and heavy brow ridges. Their tails vary in length. Their ischial callosities are prominent. The large cheek pouches serve as food containers until the food can be chewed at leisure.

Perhaps the best-known macaque is the rhesus monkey with its greenish gray coat, flesh-colored face, and red ischial callosities. It is common in India, Indochina, and China and is often used as an experimental animal in laboratories. Closely related to the rhesus is the Formosan rock macaque – the only monkey on the island of Taiwan. It lives among the rocks and on grassy hillsides along the coast, feeding on sea plants, shellfish, grasshoppers, berries, and shoots. When food is scarce in these areas, the monkeys migrate to inland forests. The Japanese monkey is a macaque with a brownish coat, bright red face, and stubby tail.

The crab-eating macaques, common in Burma, Malaysia, Indonesia, and the Philippines, are the only monkeys on many of the smaller islands of the southwest Pacific. These long-tailed animals frequent mangrove swamps along the ocean shores and hunt for crustaceans at low tide. They swim well. A relative, the heavy-set pig-tailed macaque of Indonesia, has a short, almost naked tail, twisted or arched forward over the back. The only African macaque is the almost tailless Barbary ape, which has a reddish brown coat and pale red ischial callosities. It lives in the mountains of Morocco and Algeria and was introduced on Gibraltar, where it has flourished from time to time, roaming free but under protection.

Black ape. The black ape *(Cynopithecus)* of Celebes is related to the macaques, but somewhat resembles the baboon because of its protruding muzzle. Small family groups or pairs of these monkeys live in trees but often descend to forest clearings to hunt food. Those living in mangroves near the coast gather mollusks, crabs, and sea worms at low tide.

Mangabeys. The long-tailed, comparatively slender monkeys called mangabeys *(Cercocebus)* dwell in the equatorial forests of Africa. Their coats range from glossy black and dark brown to smoky gray. They all have showy white eyebrows and occasionally white eyelids, too. Several species have crests of long hair on their crowns.

Baboons and mandrills. The baboons and their kin, the mandrills, do not look very much like monkeys. They have elongated, squarish, doglike muzzles and deep, narrow chests. They live almost entirely on the ground, where they move about on all fours. Their arms and legs are of almost equal length. Their hands are stubby, and the thumb and big toe are less opposable than is the case with other monkeys. Unlike the other higher primates, baboons have a well-developed sense of smell.

These big, muscular animals inhabit much of Africa south of the Sahara, living in open, hilly country, rocky outcrops, ravines and rocky cliffs. They eat nearly anything they can dig up, catch, or come upon by chance – plant roots, bulbs, fruits, lizards, scorpions, beetles, birds' eggs (particularly ostrich eggs), and honey.

The sacred, or hamadryas, baboon *(Comopithecus)* has a regal appearance. The males have great silver-gray manes over their necks and shoulders, and sit solemnly upright with a hand on each knee. When they walk, the tail arches behind in dignified fashion. Three hundred or more individuals may live together in loosely organized communities in the Sudan, Ethiopia, and Somalia, and along the Saudi Arabian coast of the Red Sea.

Other species of baboons include the olive baboon of east and west Africa, the yellow baboon of east Africa, the small Guinea baboon of west Africa, the South African chacma *(Papio)*, and the Ethiopian gelada baboon *(Theropithecus)*.

The most colorful of all the monkeys, the male mandrill (*Mandrillus*) of Guinea, has dark, gray-green fur and a purple face, with blue swellings along the sides of the red nose. It grows a yellowish beard and a dark crest on the crown of the head. The violet ischial callosities are surrounded by scarlet, naked skin. The tail is a mere stub. Mandrills keep more to forested country than do baboons, and they are much less gregarious. The closely related drill, also a native of Guinea, has a black face.

Guenons. Guenons (*Cercopithecus*) are found almost everywhere in Africa except along the Mediterranean coast and in the Sahara. They are long-tailed and very active animals, leaping agilely among the trees and using branches as springboards to launch them through the air. Beautifully colored, their overall tones vary from black and olive through greenish and reddish brown to gray. They are richly marked with white, yellow, chestnut, rust, and black. Many wear beards and others have side-whiskers. There are a great many species. They include the vervet, moustached, diana, green, mona, grivet, red-eared, pluto, and putty-nosed monkeys.

Patas monkeys. The patas monkeys (*Erythrocebus*) are reddish guenons that prefer the ground to the trees. They have long, slender legs and arms and can move rapidly. Patas monkeys are found in East and West Africa in partially wooded areas, on open plains, and in rocky desert regions.

APES

Of the modern primates, aside from man, the great apes (family Pongidae) and gibbons (family Hylobatidae) impress us most. Muscular animals, they vary in size from the one-meter gibbon to the nearly two-meter gorilla that is several times heavier than a man. The great apes have wide chests and long clavicles, or collarbones, that serve to keep the shoulders well apart. The nose has no bridge. The jaws project noticeably from the face, but the chin is recessive. Apes have fairly prominent grinding teeth, or molars, and their large, tusklike canine teeth provide weapons for attack and defense. Gibbons and the closely related siamangs have the thickened, horny areas of naked skin called ischial callosities on their rumps. Some chimpanzees and orangutans also possess these callosities.

Well adapted for an arboreal life, the tailless apes swing by their long arms, which are powered by strong muscles. With the exception of the gibbon, they cannot assume an erect stance for any length of time. They generally walk on all fours, with the weight resting on the knuckles of the hands and the outer sides of the feet. Because the arms are much longer than the legs, the apes bend forward in a semierect position. The chimpanzee will sometimes briefly walk erect, with a waddling gait, if it is holding something in its hands.

Chimpanzees. The chimpanzee (genus *Pan*) is a tree dweller. It lives in the tropical forests of western and central Africa. In general, the coat color is black or brownish black. The chimpanzee has a low, receding forehead with large brow ridges, and large, almost naked ears, which stand out from the head. There are several kinds of chimpanzees, including the black-faced, white-faced, and pygmy varieties.

Chimpanzee family parties spend their time moving about, sometimes in the trees but more often on the ground, searching for food and resting. They eat blossoms, leaves, stems, fruits, insects, and birds' eggs. They swallow some foods whole and chew others, spitting out the pulp. They are messy feeders and waste a great deal of food.

When resting in a tree, the chimpanzee hangs on to an overhead bough and squats on the limb below, leaning against the tree trunk. On the ground, the animal constructs day beds of leafy branches in a shady spot. While the adults rest, young chimps wrestle and engage in mock combat. The animals spend the nights in the trees, where they construct platform nests of branches, which are broken back and interwoven in such a manner that the leafy parts cover the floor. Usually each animal has its own nest. The young, however, sleep with their mothers. The nests are rarely used a second night.

Gorillas. The gorilla (*Gorilla*) is closely related to the chimpanzee. The lowland

The white-handed gibbon swings from branch to branch through the jungles of southeast Asia. It can also run at considerable speed on the ground.

Edmund Appel

gorilla inhabits the jungles of west-central Africa. The thicker-coated mountain gorilla lives on the bamboo-forested slopes of volcanic mountains in the Republic of the Congo. Both types live primarily on the ground, feeding on vegetable matter and climbing when necessary to pick fruits.

Gorillas are impressive, muscular animals, the giants among primates. They have wide shoulders. Their arms are shorter, comparatively speaking, than those of the other apes. The gorilla's eyes are set deep under a massive brow. Its small ears are close to the head. The flat nose is widely spread. The rear of the skull is buried in large and powerful neck muscles. Adult male gorillas have a crest of bone running from behind the low, narrow forehead over the top of the skull. This crest is an additional anchorage for the powerful temporal muscles that tighten the jaws when the animal chews.

Gorillas lead nomadic lives, moving in small family groups, headed and guarded by an adult male. When in the trees, the animals move about on all fours on large branches or walk erect, grasping the bough above. At night they lodge in temporary nests of branches placed in a tree fork, at the foot of a tree, in clumps of saplings, or in other spots where nesting materials are within easy reach.

Orangutans. Unlike the gorilla and chimpanzee, the orangutan *(Pongo)* is almost completely arboreal. Hanging from a bough, it uses its arms and legs alternately to travel through the trees at a fair pace. It also swings by its arms, but apparently does not leap. On the rare occasions when it descends to the ground, it walks on all fours or shuffles along in an erect position with the arms raised overhead as balancers.

The orangutan lives in swampy forests on the islands of Borneo and Sumatra. The adult males, which may stand one and one-half meters tall, have long beards and flattened, semicircular cheek pads of skin at the sides of the face. A large, inflatable throat pouch hangs down upon the chest. The shaggy coat is of reddish or yellowish brown hair. The orangutan has a bony crest over the top of its skull, and the back of the head is imbedded in the neck muscles. Its forehead is higher than that of either the gorilla or chimpanzee and it lacks heavy brow ridges. The lips protrude. The ears are small. The arms and hands are so long that when the animal stands, its fingertips touch the ankles.

The orangutan travels in very small family groups. At night each ape makes a platform nest. Sometimes, too, a nest for a siesta is constructed during the day. When food is scarce, orangutans migrate.

Gibbons. The slender gibbon *(Hylobates)* is the most accomplished acrobat of all the apes. Its flexible shoulder joints permit great freedom of arm movement. Its long hands fasten onto branches like hooks. The animal seizes a branch with one hand, then it swings forward to grasp the next branch with the other hand, and in this way, sometimes covering three meters in a single swing, it almost literally skims through the forest canopy at amazing speed. To leap, the gibbon swings above the level of the branch and hurls its body forward with bent arms raised and ready to grasp the next branch. Sometimes the animal glides outward and downward – body almost horizontal, arms and legs bent but extended – to reach a bough far below.

This agile ape walks and runs upright at considerable speed on the ground or high on a stout limb. In walking and running, it sets one foot directly in front of the other. It tilts the body slightly forward from the hips, bends the knees a little, and holds the arms up, bent at the elbows and hands drooping.

The gibbon's arms are very long, allowing the fingertips to touch the ground when the animal stands. Its nose bridge is more prominent than that of the other apes. The gibbon would look quite human if it were not for the fairly heavy brow ridges and the low, sloping forehead. It supplements its vegetable diet with insects, birds' eggs, and young birds. Its formidable piercing canine teeth not only tear tough skins from fruits but are effective weapons.

Most gibbons live in small family parties. They are vociferous animals, particularly at sunrise and sunset. At night, they do not make nests but seek shelter in heavily leafed trees.

Several species of gibbons live in the upland forests of Burma, Thailand, other parts of southeast Asia, Malaysia, Sumatra, Java, and Borneo. Their thick and woolly coats vary in color from black and brown to straw, gray, and white. The black gibbon has a crest of hair on the top of its head. The siamang *(Symphalangus)*, which inhabits Sumatra, is a close relative of the gibbon. Its well-developed inflatable throat pouch distinguishes it from the true gibbon. Siamangs have a web of skin connecting the second and third toes; such webs sometimes occur in true gibbons and chimpanzees.

PRIMATE BEHAVIOR

Many of the primates, especially the higher primates, have evolved complex patterns of behavior.

MATING AND CARE OF THE YOUNG

The various species of primates reach puberty, or sexual maturity, at different times. In chimpanzees, gorillas, and orangutans, puberty occurs at the age of 8 or 10. The gibbon reaches puberty in 7 years; baboons and other Old World monkeys, in 4 to 6 years; marmosets, in only 14 months. The life span is about 40 years for chimpanzees, 29 years for rhesus monkeys, 27 years for orangutans, and 25 years for gibbons, guenons, and yellow baboons.

The higher primates differ from most mammals in that they have no definite mating period. Males are prepared to mate at any time, while the females, unless pregnant, go through a reproductive cycle in which they are more receptive at certain times than at others. The female carries the developing young in her womb for a considerable time. This period – the gestation period – varies with the different higher primates. It ranges from 145 days in the marmoset to between 8 and 9 months in the chimpanzee. Most of the higher primates have only a single young at one time. However, the marmoset may bear 2 or 3, the sacred baboon 2, and the chimpanzee 2.

Infant primates, born feeble and helpless, live entirely on their mother's milk for at least a month before solid food is taken. The chimpanzee young, however, may nurse for two years and the orangutan even longer. A mother chimpanzee carefully grooms her young's fur with her lips, teeth, and fingers.

The mother primate carries her infant wherever she goes. When the baby is quite young, it clings to its mother's abdomen, burying its hands and feet firmly in her fur. The mother may clasp the infant with one arm as she moves from one place to another. As young monkeys and apes get older, they cling to the mother's arm, leg, or hip.

Finally they ride on her back.

The mother carefully watches the first independent movements of her offspring, assisting it when it falls and helping it to climb. Mother spider monkeys and howlers aid their young across wide spaces in the trees by bridging the gaps with vines or branches. After weaning the infant, the mother primate tests each piece of food before the baby receives it. She supervises the young when it begins to gather food.

Apparently the brunt of infant care falls upon the mother in the case of apes and Old World monkeys. However, the males of some New World monkeys seem to share in this responsibility.

SOCIAL GROUPS

Higher primates live together in well-organized social groups. The size of the group depends particularly upon the food supply in a given territory. When this supply is unable to support all the individuals, small groups break away and move.

New World monkeys usually congregate in *clans*. The typical spider and howler monkey clan numbers about three adult males, eight mature females, and a number of juveniles. The smaller American monkeys apparently live in pairs accompanied by their semidependent young. Sometimes capuchins associate with spider monkeys or squirrel monkeys. Though the males of many species live singly, the unmated male spider monkeys form troops.

The New World monkeys show a decided lack of domineering traits. Males of the howlers and other American monkeys never fight for food or females. Spider monkey males even share leadership of the clan with their females. Among the howlers, a male is usually in command, but no male is a permanent leader.

The smallest basic social unit among apes and Old World monkeys is the *harem*, in which a dominant adult male, or overlord, holds sway over several adult females and young of various ages. (The gibbon is an exception, for only one adult female and her young accompany a male.) Harems may unite to form large troops, or, as in the case of the baboons, herds of over a thousand individuals. Bachelor males, especially baboon and rhesus bachelors, accompany the harems, on the watch for unmated females. Some males live alone.

One of the most powerful social forces among the Old World monkeys is *dominance*. A dominant animal lords it over his subordinates, especially females. This tyrant is more vigorous and a better fighter than the rest. He has an aggressive, confident attitude. He always feeds first, driving away the other members of the group until he is satisfied. He assumes leadership in exploration and movements. The lesser members of the troop dominate their inferiors but cringe before their superiors.

Inferior monkeys sometimes indicate their subordinate position by presenting their hind quarters to their superiors. Young baboons, for example, make this sign of deference to adults and to their more dominant playmates. Presenting the hind quarters may also be the equivalent of a friendly greeting. Baboons in captivity will present to persons of whom they are fond.

Gorilla and orangutan overlords maintain their positions by defeating young adult males who oppose them. When a dominant gibbon finds food, it will gather as much as it can carry and make way for the others. A dominant chimpanzee does not lord it over his inferiors. He protects them and shares his food with them.

COMMUNICATION

Primates communicate with one another by vocal sounds and varied facial expressions. These expressions, often enhanced by smacking the lips and rhythmically moving the tongue, lips, and jaws, signify pleasure or annoyance, hunger or contentment. An angry gibbon, for example, threatens by opening and closing its mouth, clicking its teeth, and smacking its lips. An angry male rhesus or baboon exposes its canines.

With growls, grunts, twitterings, chirpings, whispers, barks, screams, and cries, apes and monkeys warn of danger, indicate alarm or distress, and keep the scattered individuals of the clan or family in touch with one another. For instance, the barking roar emitted by howler monkey males when a rival clan appears has the effect of stopping all feeding, playing, and exploring and brings about a defiant attitude. A leading male gives a deep, hoarse cluck to start the clan moving and control its direction. A female howler wails in distress when her young falls. The youngster itself makes little cries that indicate its position to the adult howler.

Body postures and attitudes also indicate emotion or act as a signal for flight, defense, or attack. An enraged gibbon, for example, jumps up and down and shakes the branch on which it is standing. To express emotion, a chimpanzee bounces up and down on bent legs, stamps its feet on the ground, or drums on a hollow log with its hands and feet. The gorilla stamps its feet, strikes the ground rhythmically with its hands, and beats its chest. Young howlers learn that certain actions of the mother indicate that she is going to move, and accordingly they run to her and climb upon her so that she may carry them.

Grooming is another feature of primate society. The grooming habit is practiced on oneself or on another; mutual grooming is a sign of friendliness and sociability. The groomer goes over the ears, neck, shoulders, back, and rump of its partner, using its fingers to spread the fur while grooming with the other hand and feet, nibbling with its teeth, or licking with its tongue. The object is to clean the skin of scaly, loose fragments and particles of secretions, to squeeze carbuncles, and to remove thorns. Grooming apparently gives sensuous satisfaction. The groomed animal sits or lies in a relaxed attitude with closed eyes. The purpose of grooming, by the way, is not to remove vermin, since primates are usually free of mites or fleas.

The preoccupation of apes and monkeys with fur and hair is often truly amazing. Captives apes and monkeys show an intense desire for fur rugs, for the hair of other animals and even for brooms.

TERRITORIES

Monkeys and gibbons, as far as we know, restrict their wanderings to a more or less well-defined territory. A troop or clan may live in an area covering from 12 to 120 hectares. Sometimes this territory adjoins or overlaps that of another troop or clan. The most important factors determining the extent of a given territory are the number of individuals in the group or clan, the abundance of food, and the presence of suitable trees in which to lodge at night and play and rest during the day. If the food supply diminishes or the group gets larger, the territory is expanded or abandoned for a better one.

Old World monkeys sometimes fight fiercely for their territories against all rivals. Rival groups of howlers, on the other hand, engage in a duel of roaring until one group retreats. Spider monkeys break off dead branches and drop them on intruders, particularly humans.

In a course of a day's wanderings, monkey and gibbon groups follow arboreal trails of intertwining branches that lead to favorite food and shelter trees. Spider monkeys travel over the same definite aerial highways each day. They feed, take siestas, and lodge for the night in the same trees. Howlers, on the other hand, may travel only a few hundred meters in one day. They may remain in the same spot for several days if food is abundant. When they reach the boundary of their territory, they turn back toward the area they covered several days before. If the clan is searching for a new route, each adult male explores a different avenue. When a suitable trail is found, the successful male returns to the clan, emits a deep clucking sound, and signals for the clan to follow him.

The ground-dwelling baboons also travel over a fairly definite area each day. They scatter as they feed during the daytime, but they come together at night in rocky retreats. On rare occasions, when food becomes scarce, baboon colonies migrate to a new territory. Certain mangabeys engage in seasonal migrations. Bands of these monkeys meet in the same place and at the same time each year.

LEARNING

Primates in captivity are interesting to observe and study. Generally speaking, ape and monkey youngsters are docile and friendly, though quite destructive. Young chimpanzees are particularly destructive. They toss their arms and legs wildly, jump up and down, pound the ground, contort their faces in a variety of grimaces, and show their intense delight when they are praised or applauded. If placed in the company of the more deliberate gorilla, the chimpanzee almost always becomes the leader in all activities and acts as a protector to its companion.

Most monkey and ape adults in captivity are apt to be temperamental and unreliable. Adult dominant primates, especially Old World monkeys, will attack sick and weak companions and exhibit great selfishness at feeding time.

Studies of the higher primates in captivity have proved definitely that they can adapt successfully to novel situations. Most of them can use sticks, pieces of wire, floor brushes, and so on to reach food placed outside their cages. They quickly learn to unfasten various complex catches that lock doors behind which food has been placed. They can discriminate between colors, use table utensils, saw, drive nails with a hammer, put on clothes, ride tricycles, and open padlocks with keys, among other striking examples of learning ability.

Chimpanzees can learn how a key works in a lock, and if no key is available, they will try to use a substitute. The standard test for determining a chimpanzee's reasoning powers is to scatter boxes in the cage and suspend fruit high above the ape's reach.

The time taken for the chimpanzee to stack the boxes below the fruit will provide some measure of his intelligence. One chimpanzee was given a long pole in place of the boxes. Instead of knocking down the fruit, the ape set the pole vertically below the suspended fruit, quickly climbed the pole, grabbed the prize, and dropped to the floor before the pole toppled. Another chimpanzee was offered two sticks, neither of which was long enough to rake in food outside the cage. It fitted the smaller stick into the larger one, solving the problem in this way.

SYMBOLIC BEHAVIOR

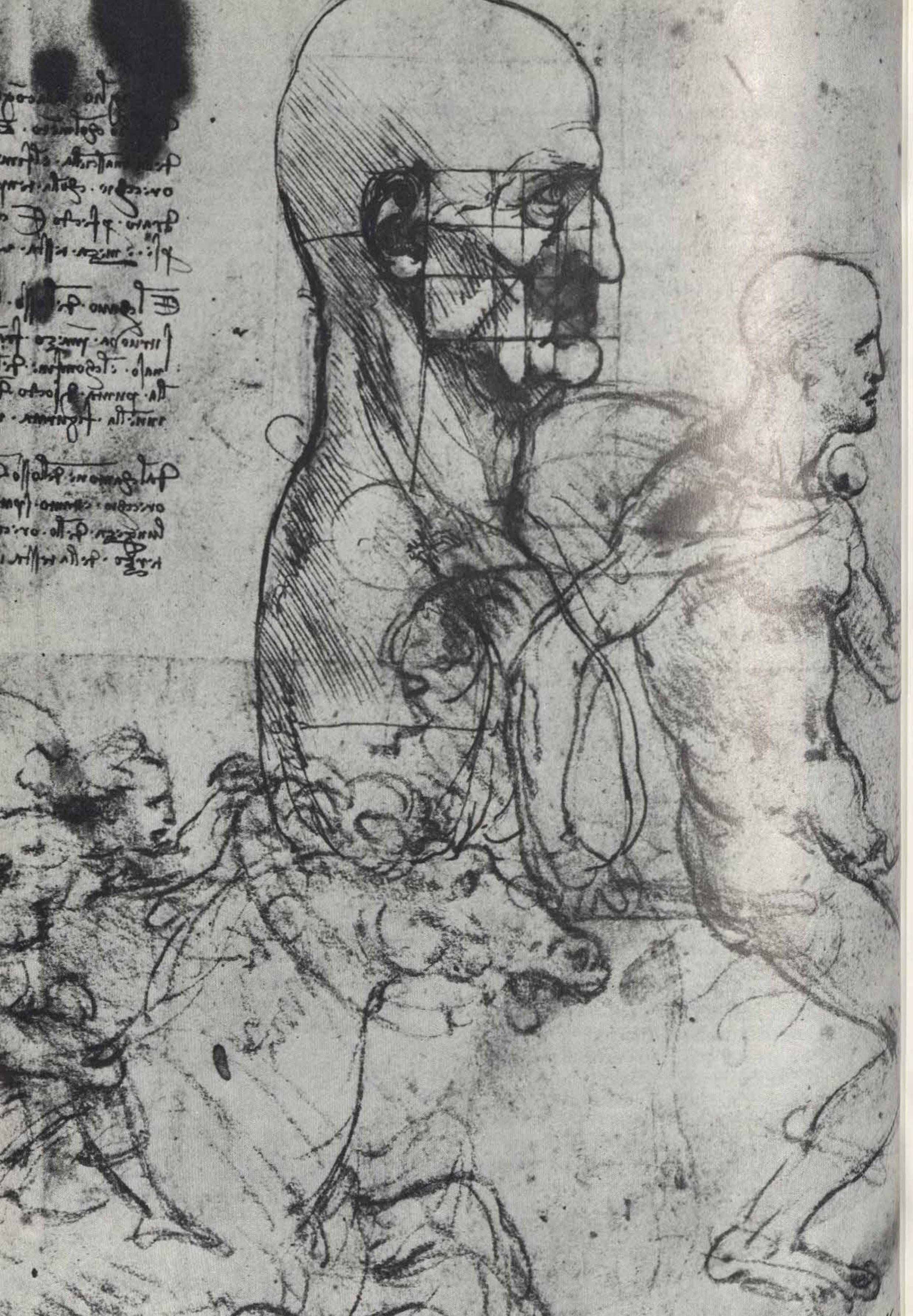
Chimpanzees also show a marked degree of symbolic behavior; that is, they can understand the relationship between a material object and something else that it represents. At the Yale University Laboratories of Primate Biology, chimpanzees were given poker chips with which to play. At first the chips meant little to the apes, but when a grape was offered in exchange for a chip, the disks became valuable.

Later a device called the Chimp-o-mat was installed in the apes' cage. The animals soon learned that when they inserted poker chips of different colors in the Chimp-o-mat, they would obtain grapes, a drink of water, or a piggyback ride on one of the laboratory scientists.

To complicate matters, a work machine was provided, by which the chimpanzees operated a weight handle to earn poker chips. These chips could then be spent in the Chimp-o-mat. In other words, the chimps were working for pay. They treasured and hoarded their chips, but paid no attention to brass slugs when they discovered these slugs would buy nothing from the machine.

Another curious display of symbolic behavior was exhibited by a young female orangutan who was taught to say the words "cup" and "papa." Apparently she knew what they meant, for when she was thirsty she said "cup," and when she was frightened the orangutan called her trainer by crying "Papa!"

Because higher primates do not have the same vocal equipment as humans, they cannot be taught to speak more than a few words. Some chimps and gorillas have, however, been taught to use American Sign Language, and can communicate with their trainers. A gorilla named Koko acquired a working vocabulary of about 375 signs. Some chimps learned to "read" plastic symbols and to use them to "talk" to researchers. One chimp, named Lana, was taught a special language. She learned to communicate with humans, expressing her desires and feelings by typing this special language on a computer typewriter.



HUMAN SCIENCES

Left: Alinari/Scala
Above: WHO

Human beings are the only creatures that can study themselves. Such study began with simple observations of the body and now includes complex medical and psychological studies. Opposite page: a study of the human head and body in motion done by the 15th-century artist-scientist Leonardo da Vinci. Above: a medical success story. Smallpox, once a dread disease, has now been almost eradicated —thanks to vaccination programs such as the one depicted in the poster.

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THE HUMAN SPECIES

Homo sapiens, or modern man, is one of the most successful living organisms. The success of humans on the earth is related to their ability to change their local environment, making it suitable for human habitation. Because *Homo sapiens* has been able to farm effectively, domesticate and raise animals for food, create more durable dwellings, and cure diseases that afflict people, the human species has been able to grow to a population size eight times what it was 4,000 years ago.

Because of their high intelligence and advanced tool-making and tool-using abilities, human beings consider themselves apart from the animal world. But, human beings are indeed animals, and they are subject to the same biological processes as animals. For one thing, the human body is made up of the elemental life substance called protoplasm, found in all living things, though differing somewhat in composition in different species. Like other creatures, humans have structures and organs for supporting the body, breathing, circulating the blood, digesting foodstuffs, eliminating wastes, perceiving the world, and reproducing. Present theory holds that the human body is the product of organic evolution, a biological process of creating new forms that has been in operation for millions of years.

A VERTEBRATE

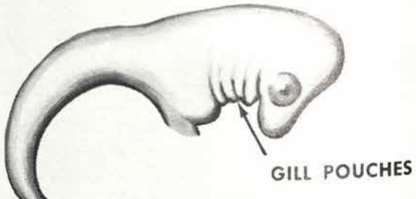
What is our place in the animal kingdom? First of all, we are vertebrates—animals that have a backbone. Fishes, frogs, snakes, birds, whales are all verbebrates. A feature in the development of vertebrates is the *notochord,* found in the most primitive of vertebrates, the *Amphioxus.* The notochord is a long rod of tough tissue to which muscles attach. In the embryos of all vertebrates, the notochord appears; it is later replaced by the cartilaginous or bony vertebral column.

Above the notochord, a hollow tube of nerve tissue develops. It becomes the spinal cord. In the head end of the organism the spinal cord becomes enlarged and modified forming the brain.

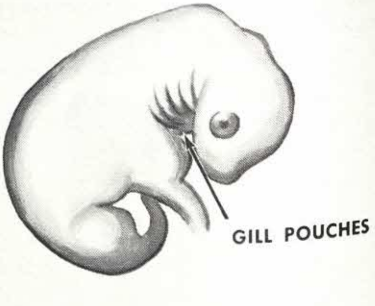
A MAMMAL

In the second place, human beings are mammals. Generally speaking, mammals are four-limbed, active creatures with more or less well-developed brains. They have great capacity for learning and some show keen intelligence. The body covering of hair and the sweat glands in the skin help maintain a high and constant body temperature. There are three kinds of teeth—incisors, canines, and molars. There is a four-chambered heart, and a big artery—the *aorta*—leading from one of the chambers. Blood flows through this artery to all parts of the body. Separating the chest cavity from the abdominal region is the *diaphragm,* a muscular sheet that aids in

All vertebrates possess gill pouches at some time during their development. Below are shown the gill pouches of a fish embryo and those of a human embryo. In humans, the pouches represent a passing stage in the growth of the embryo.



FISH EMBRYO



HUMAN EMBRYO

breathing. The young mammal is typically carried as an embryo within the female's body and is born alive. Only the most primitive mammals do not have this process. All mammalian young are nourished on milk secreted by the mammary glands of the mother and are cared for during a more or less extended period after birth.

A PRIMATE

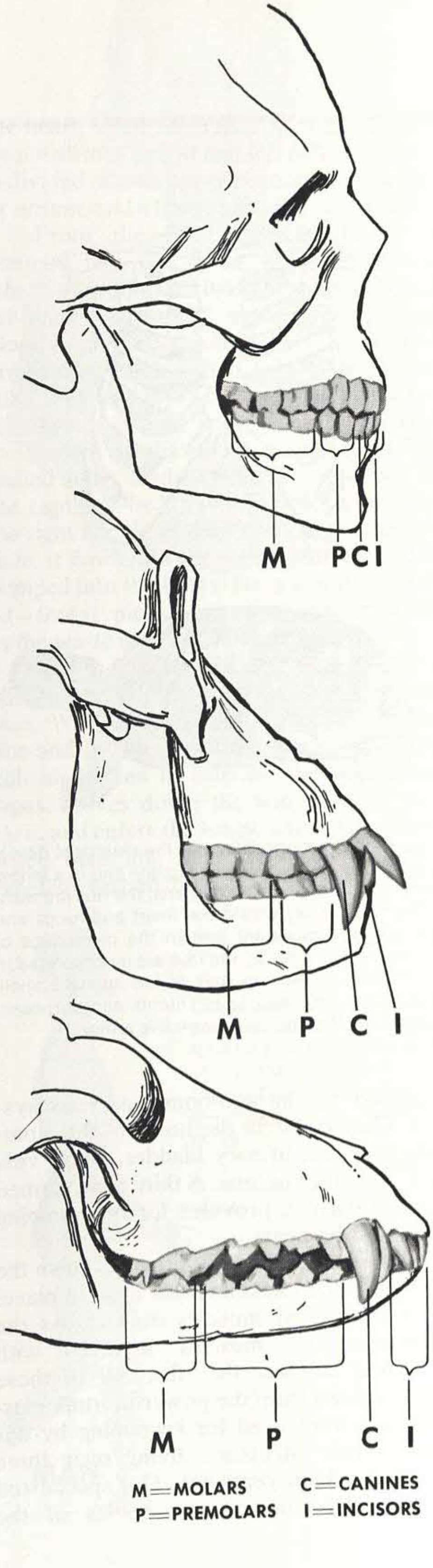
Homo sapiens is also a primate—that is, he belongs to the mammalian order of primates, which includes the lemurs, tarsiers, monkeys, and apes. Most primates are well adapted for living in the trees. They have grasping hands and feet. The thumb and first toe can be moved so that they are opposite the other digits of the hand and foot. Only the thumbs are opposable in humans. The limbs are quite flexible, especially the arms. Primates are more or less flat-faced creatures with a large cranium, small nose, and forward-directed eyes. They have larger and better-developed brains than any other mammals. Their vision is very acute and their hearing is good. Since they are agile and can react quickly, they can adapt themselves to varying circumstances.

STRUCTURE OF THE HUMAN BODY

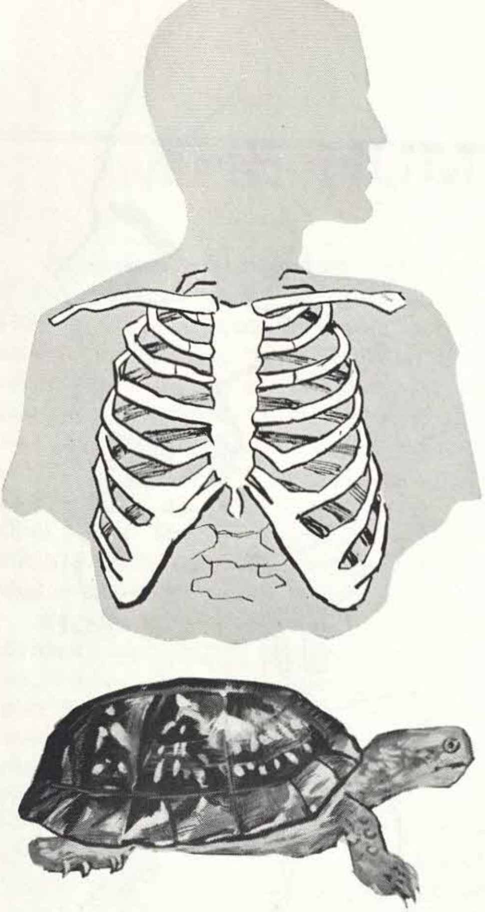
Homo sapiens is a big-brained primate who walks erect. Let us briefly examine the structure of the human body and some of its functions.

MUSCLES

The muscles are built up of bundles of highly active, long, and slim muscle cells. When these cells contract in unison, they are capable of moving the bones to which their ends are attached. The muscles that account for body movement—the *skeletal muscles*—are under our voluntary control. Others, known as the *smooth muscles,* are



Vertebrates have basically three kinds of teeth—incisors, canines, and molars. Canines are lacking in some vertebrates; in others, there is a fourth type of teeth—the premolars. The drawing shows the molars, premolars, canines, and incisors of a human being, gorilla, and dog. Note the prominence of the canines in the dog and gorilla.



These two drawings illustrate the divergent development of the ribs in *Homo sapiens* and in a fellow vertebrate—the turtle. In humans, the ribs are within the body. They shield the heart and lungs and also play an important part in the mechanics of breathing. In the turtle, the ribs are incorporated in the carapace—the top part of the animal's shell. Thus the turtle's ribs, to all intents and purposes, form part of the animal's protective armor.

governed by the autonomic nervous system. They occur in the lining of the stomach, intestine, urinary bladder, blood vessels, and other organs. A third type, termed *cardiac muscle*, provides for the pumping action of the heart.

The skeletal muscles that go down the back hold the backbone and head in place. A thin sheet of muscles runs across the abdomen, and muscles involved with breathing connect the ribs. All of these have evolved from the powerful trunk muscles that were used for swimming by our ancient fish ancestors, living over three hundred million years ago. Our specialized eye muscles and some muscles of the tongue are also derived from these trunk muscles. The other muscles of our head and throat, including those of the jaw and of expression, were long ago linked with the gill bars. They functioned as part of the underwater breathing apparatus of our ancestors.

In humans, strong limb muscles connect the arm and leg bones with the body. In the upper arm and upper leg, we have big muscles that open and close the elbow and knee joints. Attached to the forearm and foreleg are the muscles used for manipulating the hand and foot. Numerous small muscles control the intricate movements of the fingers and toes. These limb muscles developed when our fishlike vertebrate ancestors first evolved legs and scrambled from the water onto the land.

BONES

The skeleton has several functions. For one thing, it provides effective protection. The brain is shielded by the bones of the skull; the spinal cord, by the arches of the backbone; the chest cavity, by the ribs and breastbone; the organs of the lower abdomen, by the basinlike pelvis. The bony framework also supports the body's soft organs. The bones offer surfaces for the attachment of muscles. They store calcium and phosphorus, which are released when the body needs these essential minerals. Some bones are quite compact. They are pierced only by small canals that carry blood vessels. Other bones, especially the larger ones, are filled in the center with marrow, where blood cells are formed.

Bone contains branching cells that rest in a network of minute interlacing fibers, reinforced with calcium phosphate and calcium carbonate. In the development of our bodies, bone is usually preceded by cartilage, a firm but flexible material. As development proceeds, bone gradually replaces the cartilage. In the adult, cartilage occurs as disks between the bones of the backbone, at the tip of the nose, in the external ear, at the ends of the ribs, and at the surfaces of the limb joints.

The lower jaw bone, the collarbone, and much of the skull are not preceded by cartilage but develop directly from connecting tissue underlying the skin. These bones are remnants of the surface armor that once covered the earliest fishlike vertebrates. In the human embryo, there are hundreds of bony elements. As growth and development take place through childhood on into maturity, many of these elements fuse together. In middle age there are only a little over two hundred separate bones.

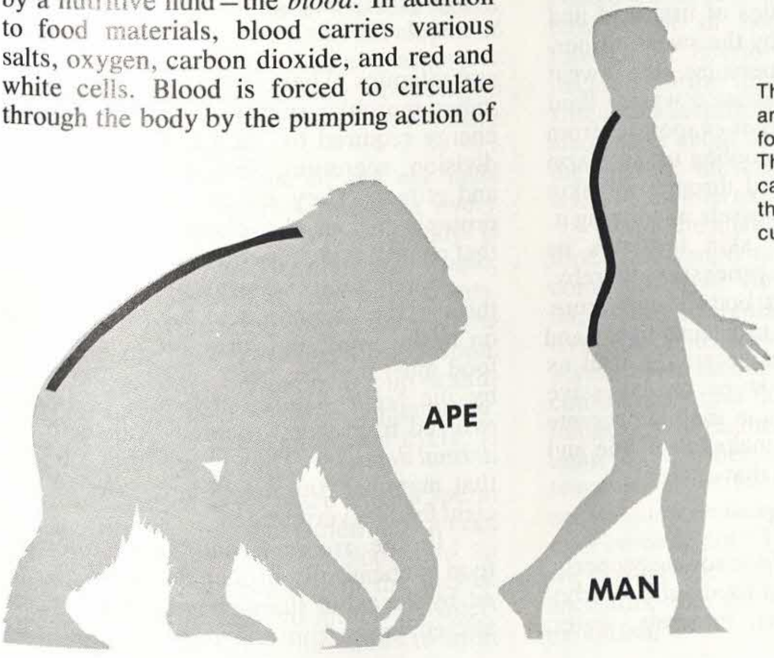
The backbone of four-limbed animals, including the apes, forms a simple curving arch. Because of man's erect posture, his backbone is thrown into an S-shaped curve. The second curve – the small of the back – brings the body's center of gravity directly above the hips so that head and chest are balanced above the hip region. The fused hip bones, attached to the base of the spine, form a girdle that transmits the weight of the body to the legs. The bone of the heel gives a solid support to the foot. From the shoulder girdle, made up chiefly by the shoulder blade, the bones of the arm hang freely.

BLOOD AND BREATHING

Bone and muscle as well as other tissues and organs must be bathed continually by a nutritive fluid – the *blood*. In addition to food materials, blood carries various salts, oxygen, carbon dioxide, and red and white cells. Blood is forced to circulate through the body by the pumping action of the heart, a hollow muscular organ divided by a wall into a right and left half. Each half is divided into an upper portion, the *auricle*, or *atrium*, and a lower part, the *ventricle*.

From the left ventricle, blood is pumped into the *aorta*, or great artery, which soon gives off branching arteries that rebranch again and again, transporting blood to all parts of the body. The arteries are strong, thick-walled tubes. In the tissues, they lead into a bed of minute capillaries, through whose walls passes the blood fluid with its dissolved materials. Thin-walled veins, leading from the other end of the capillary bed, carry the blood back to the right auricle of the heart. From this auricle, it flows into the right ventricle and is pumped into the lungs. Here it is oxygenated – that is, picks up oxygen – and it releases the waste material carbon dioxide.

Our *lungs* are highly elastic organs filled with millions of tiny, membranous air sacs. When we breathe in, by raising the ribs and lowering the *diaphragm*, oxygen-rich air comes in through the nasal passages, moves down the windpipe, or *trachea*, and enters the lungs, expanding them. When breathing out, the lungs collapse, expelling carbon dioxide and water vapor.



The backbone of four-footed animals, including the apes, forms a simple curving arch. The backbone of man, because of his erect posture, is thrown into an S-shaped curve.

From the lungs, blood travels to the left auricle of the heart, then to the left ventricle, and again out of the heart by way of the aorta. The division of the heart into a right and left half is a most efficient way of keeping the oxygenated blood separated from that which is unoxygenated.

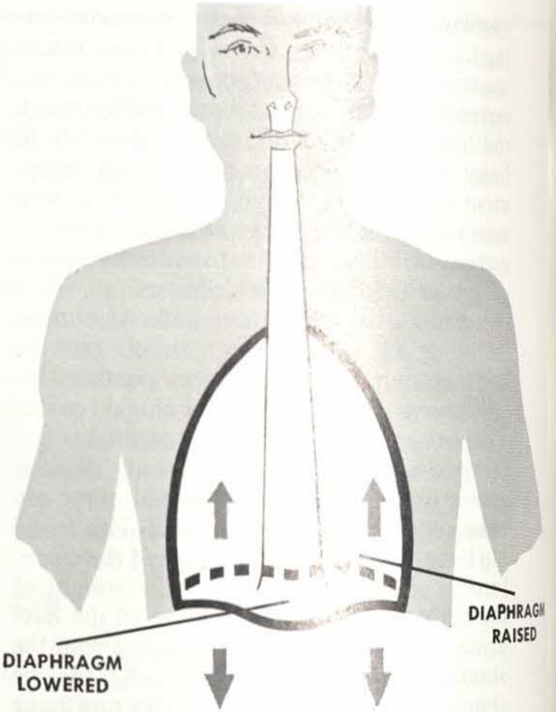
WASTE DISPOSAL

In circulating around the body, the blood passes through the *kidneys,* two bean-shaped organs situated in the region of the small of the back. In the kidneys, blood is first filtered of its water, salts, sugar, and such wastes as urea, uric acid, and ammonia. Then most of the water and salts and all of the sugar are reabsorbed and pass back into the blood vessels. The wastes and some water and salts leave the kidney in the form of concentrated *urine*. The urine flows from the *kidney* to the *bladder* via *ureters* and from here out of the body by way of the duct called the *urethra*. By its filtering and absorbing mechanisms, the kidney not only eliminates wastes from the blood, but also maintains the blood's composition and its acid-base balance.

The skin also excretes wastes, but only in small amounts. A certain amount of carbon dioxide escapes from the blood through the skin. Small quantities of uric acid and urea are carried away by the sweat, or perspiration. When we perspire, the sweat glands in the skin withdraw a watery fluid from the blood. This sweat evaporates from the body surface, thus cooling us. In warm weather, heat is radiated through the skin from the dilated blood vessels underlying it. In cold weather, the skin insulates us against the cold. Both processes, thereby, help ensure a constant body temperature. The skin, too, protects us against injury and the invasion of disease germs, as well as against excessive moisture or excessive dryness. Certain glands in the skin secrete an oily substance that makes it pliable and lubricates the fine hairs that cover it.

FOOD AND DIGESTION

To keep the body functioning properly, we must eat a variety of foodstuffs – carbohydrates, fats, proteins, minerals, water, and vitamins. These are necessary for providing muscular energy, body heat, and the energy required by such processes as cell division, secretion, absorption, excretion, and growth. They are needed for building protoplasm and the chemical substances that control body functions.



Whenever we breathe in, by raising the ribs and lowering the diaphragm, air that is rich in oxygen is drawn into the lungs by way of the nasal passages and the windpipe, and the lungs expand. When we breathe out, the diaphragm is raised and the ribs are lowered. The lungs contract, expelling carbon dioxide and water vapor.

When food is swallowed, it passes through the *esophagus* to the *stomach* and on to the *small* and *large intestines*. Solid food must first be mechanically broken up by the *teeth*. These structures originally evolved from small pointed skin teeth, or *dermal denticles*. They jutted from the skin that margined the developing jaws of ancient fishlike vertebrates.

In the *stomach* and *small intestine* food is chemically broken down, or *digested*, by the aid of stomach enzymes, pancreatic enzymes from the *pancreas*, and bile from the *liver*. The now soluble food material is absorbed through the lining of the small intestine. Water is absorbed by the *large intestine*. This organ also stores the solid digestive wastes, or *feces*, before they are eliminated. The absorbed nutrients are picked up by the blood and carried to all the cells of the body. Here the food is *metabolized*—that is, chemically changed to yield energy and build protoplasm.

HORMONES AND REPRODUCTION

The *endocrine glands*, or glands of internal secretion, play an important part in the digestive process through the chemical substances, called *hormones*, that they release into the blood stream. Hormones from the *adrenal glands* affect the metabolism of fats, proteins, and carbohydrates and ensure the proper balance of minerals and water. Hormones from the *thyroid gland* stimulate the combustion of food materials in the cell. Those from certain gland cells in the pancreas govern the metabolism of sugar.

Endocrine glands also play an important part in reproduction. The glands known as *ovaries* are responsible for the development of the female sex organs and milk glands. The comparable glands in the male—the *testes*—govern the development of the male sex organs and sex behavior. Female sex cells, or *eggs*, are produced by the *ovaries*. Male sex cells, or *sperm*, are produced by the testes.

Normally, only one of the egg cells produced by the ovaries ripens in every twenty-eight days. The female's body is geared for this event. The *uterus*, or womb, is prepared to receive, or implant, the fertilized egg. If fertilization does not occur, the lining of the uterus breaks down. Soon, however, the uterus is again built up in anticipation of the next possible implantation. This cycle, called the *menstrual cycle*, is controlled by hormones.

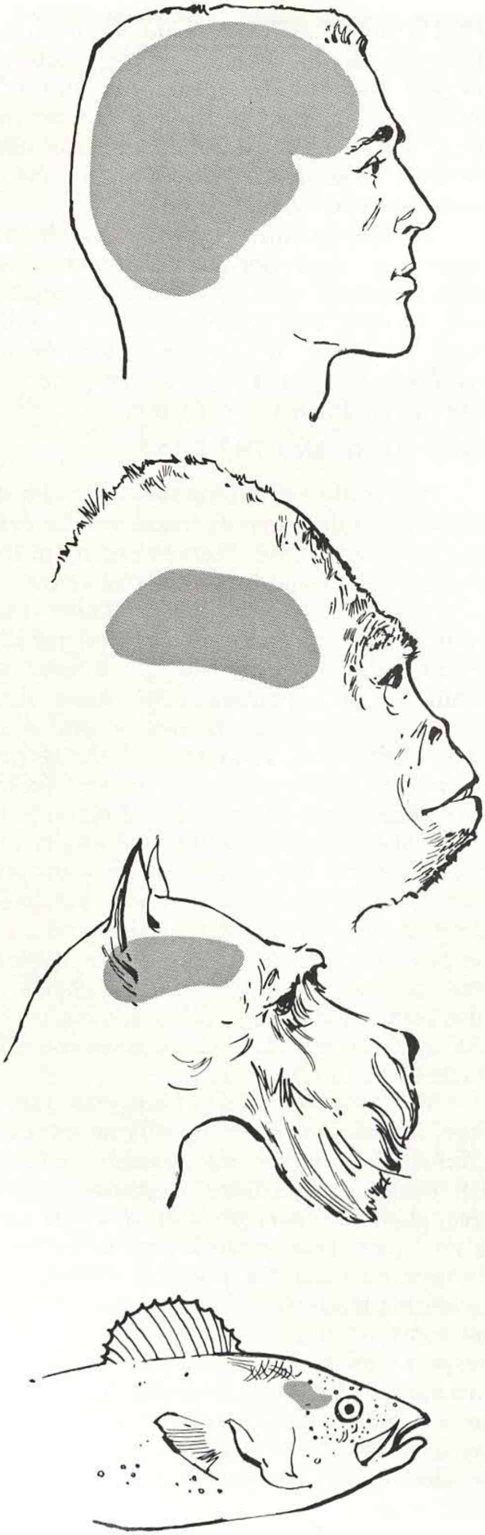
Fertilization takes place when a sperm succeeds in reaching and penetrating an egg cell. The fertilized egg develops into an *embryo*, which is enclosed in the uterus. Tissues from the embryo intimately interlock with tissues lining the uterus to form what is known as the *placenta*. Through the placenta, the developing young receives oxygen and nutrients, from its mother's blood, and passes out carbon dioxide and other wastes. After a period of about nine months, development within the uterus is complete, and the baby is born.

The endocrine glands, through the agency of their hormones, preside over such relatively slow processes as metabolism, growth, and development. The more rapid activities of muscular movement, gland secretion, and thought are under the direction of the nervous system.

RECEPTORS AND THE BRAIN

The *brain* and the *spinal cord*, with its branching spinal nerves, make up the *central nervous system*. Nerves ending in the skin receptors and in the special *sense organs*, such as the *eye* and *ear*, receive stimulation from the outer world and rapidly transmit impulses to the spinal cord or brain. Nerve impulses from these then speed to the appropriate muscles and stimulate their action. Thus, through the agency of the central nervous system, we gain information about the world and respond to such information. Our internal affairs are controlled by the autonomic nervous system, a set of nerves widely scattered through the interior of the body and connected with the spinal nerves. This system stimulates secretion from various glands. It also brings about appropriate movement of the smooth muscles which compose the walls of the internal organs.

From the anatomical viewpoint, therefore, *Homo sapiens* represents an intricate combination of various systems—muscular, skeletal, circulatory, excretory, digestive, glandular, nervous—all of which play a vital part. Human anatomy, as we have considered it thus far, presents nothing particularly remarkable, when compared to the anatomy of other mammals. Yet in some respects, as we have pointed out, humans are unique creatures. How did this uniqueness come about? To answer the question, we must go back in time to humans' primate ancestors and see what factors led to our evolution.



EVOLUTIONARY TRENDS

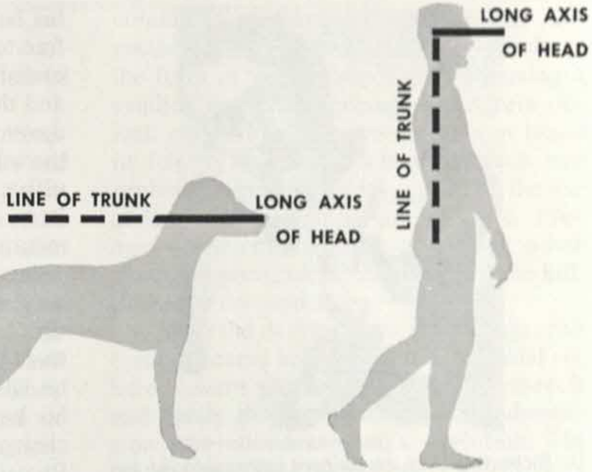
Life in the trees had made the primates alert and agile animals. They had developed excellent muscular coordination. They could leap or swing from one branch to another, maintain their balance, and be ready to make another movement.

They depended on eyesight rather than smell to find food and detect enemies. Since their sense of smell was limited, a long snout was unnecessary. Consequently, the nose was reduced and the eyes shifted to the front of the face. With the eyes directed forward, the fields of vision overlapped, giving stereoscopic vision, or the ability to perceive depth. Primates also have excellent hearing.

These animals possessed a searching curiosity. Though they generally walked on all fours, they had grasping hands and feet by which they could feel and pick up objects and examine them. Perhaps they had enough insight to use sticks for knocking down fruit or dragging in objects that would otherwise be unobtainable. We know that modern-day chimpanzees show this type of behavior. They searched for potential sources of food and no doubt experimentally tasted and ate a variety of foodstuffs. Unequipped with formidable weapons of defense, except their canine teeth, they lived by their wits. They saw or heard the enemy first and made their escape by fleeing or hiding.

All of these characteristics and activities were associated with a remarkable development of the brain. This development was most pronounced in the *cerebrum* – the two large lobes that make up the most prominent part of the brain. The cerebrum of many lower vertebrates is concerned with the sense of smell. But in the primates, since the smell function is reduced, the cerebrum is primarily involved with the analysis of what is seen, what is heard, and what is touched. Above all, it controls locomotor

The comparative size of the brain in a human being, a gorilla, a dog, and a fish. The extraordinary development of the brain – particularly the part called the cerebrum – played a major role in the rise of human civilization.



In most mammals (including the dog) the trunk and the long axis of the head are on the same line. In human beings, the long axis of the head is at right angles to the line of the trunk. To see straight ahead, humans have adopted an upright posture.

activities—the complex use of muscles for climbing, swinging, jumping, running, and manipulating the fingers and toes. It is interesting to note that the seat of our higher mental faculties in the cerebrum seems to lie alongside those areas that govern muscular movements.

The life of the primate placed a premium on a well-developed brain. Natural selection preserved any brain modification that allowed the animal to adapt better to its surroundings and to survive, so that it could reproduce. The evolution of the primates, as indicated by the fossil record and living species, progressed in the direction of this greater brain development.

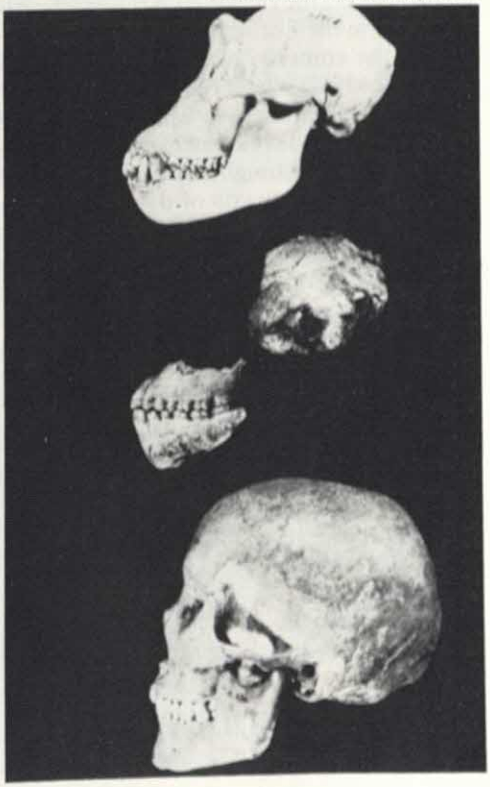
TOWARDS *HOMO SAPIENS*

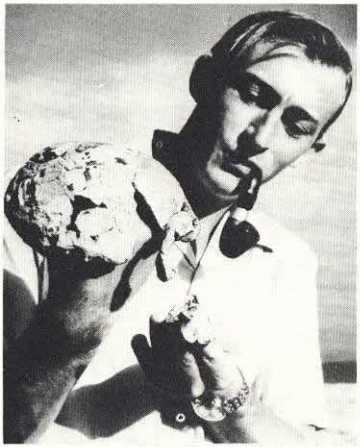
The primates that were to give rise to the human stock were four-footed animals, equipped with a good brain, excellent eyesight, and very nimble fingers. They showed endless curiosity and had a decided bent for cooperative group living, like many primates. The important factor that converted an apelike primate into a forerunner of the modern *Homo sapiens* was the adoption of an upright posture.

We do not know how this change took place. Probably a population of pioneering primates who were able to stand and walk somewhat more erect than other popula-

The fossilized jaws and cranium of an australopithecine (center), a possible ancestor of human beings, is shown with a chimpanzee skull (top) and the skull of modern man (bottom).

Cleveland Museum of Natural History from UPI





National Geographic photo via UPI

Dr. Richard Leakey, an eminent anthropologist, led the team that discovered skull fragments of a humanlike creature that lived in Africa about 1.9 million years ago.

tions found that they were now able to make a living on the ground. Since these primates survived and reproduced in this environment, they passed on the erect-posture trait to their offspring.

In the embryos of mammals, the long axis of the head is at a right angle to that of the trunk. This angle is called the *cranial flexure*. During development, this flexure in most mammals straightens out so that the trunk and the long axis of the head are on the same line. In the evolution of man, however, the embryonic cranial flexure was retained as a permanent feature in the adult. This meant that the line of vision was at right angles to the body. In order to see straight ahead, the body would have to be in an upright position. Modifications in the bones of the hip and thigh were associated with the erect stance. The bones of the foot were remodeled to form a substantial base on which the body could stand.

The earliest manlike ancestor may have arisen from a population of primates existing about 35 million years ago. These animals would also have been the ancestors of the apes.

In any case, we find that once some later, manlike ancestor stood and walked erect, new and profound possibilities were open to him. This primate no longer needed his hands for walking. They were entirely free to pick up objects, carry them, closely examine them, or throw them. His brain and the skillful use of his hands may have developed together, one dependent upon the other. Better control was developed for using the hands cooperatively. Sooner or later, one of our ancestors found by experimenting that he could use a stick as a digging tool, lever, spear, or club. Stones were employed as pounders, scrapers, or missiles. In effect, early man had invented tools by which he could shape material as he wished. Tools became an extension of his hands, a basic part of him, so that he changed his environment more and more. By using tools, new features of the environment were opened to his curiosity. The brain acted upon these discoveries and continued to develop.

The diet of ground-dwelling primates came to be more varied than that of the arboreal primates, which ate fruit, leaves, and small animals. Early man became omnivorous, adapting himself to an assortment

The making and using of tools was an important early step in the evolution of *Homo sapiens*. The first tools were stone tools. In 1971 stone-tool people living in the 20th century—the Tasaday of the Philippines—were discovered. These people may be a key to the human past.

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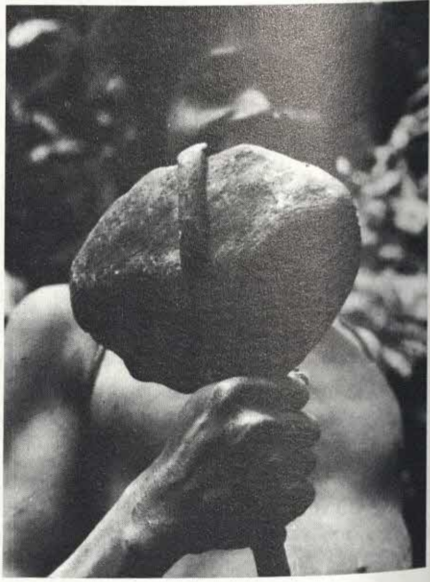

of foods. With but few restrictions on his feeding habits, he could survive under conditions that would cause a more specialized animal to starve.

The use of stones and sticks as weapons allowed our ancestors to kill bigger and faster game. Hunting together in packs, they could outwit and outmaneuver their quarry. Pack hunting undoubtedly called for cooperation among the hunters. Leadership and discipline within the ranks became an established part of this activity. The females, meanwhile, gathered food and prepared it and cared for the young. They also tended the cooking fires, the use of which had been a momentous discovery sometime during human evolution.

An important factor in cementing family relationships was the long postnatal development of the young. The mother could not easily carry her young on a hunt or extended migration, so she maintained a base where she could care for them. It is presumed that her mate brought back food from the hunt. Since development to maturity was prolonged, the young male and female had a long period in which to learn about hunting, food gathering, and the other activities of the group.

A most significant feature of man's evolution was the development of the communication system that we call *language*. This involves the use of symbols, in the form of words or phrases. By using a symbol, one can represent a concrete object, even when it cannot be seen or heard or felt. In early man's family, which was probably separated in its activities, the use of language became a uniting force. Pro-men could communicate with each other about weapons, tools, the nature of the kill, the use of fire, and so on.

With the development of language, the family became better united, and social relations were established. Through speech and finally through writing, a new dimension was added to man's evolution. He could teach his children more effectively. He could record his history and so transmit the wisdom of the past down through the centuries to the men of the present. No longer was organic evolution, or the inheritance of modifications through physical reproduction, the only force in man's development. He now had a new heredity—the passing on to his descendents of the accumulated knowledge gained by his experience.

Man's uniqueness, therefore, is associated with the development of his brain and the progress that this development has made possible.

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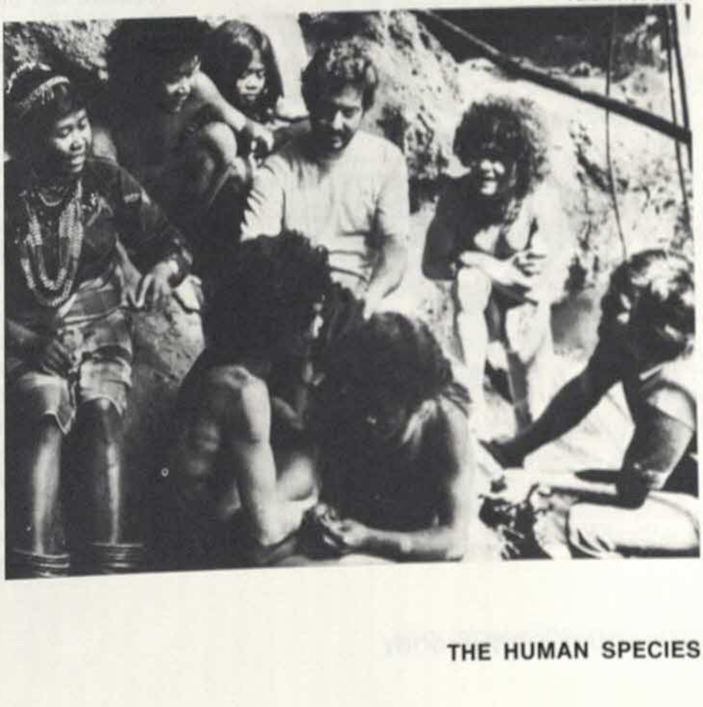


The development of language and social organization were also important steps in human evolution. Here a group of Tasaday talk of their life to one of the first outsiders to visit them.

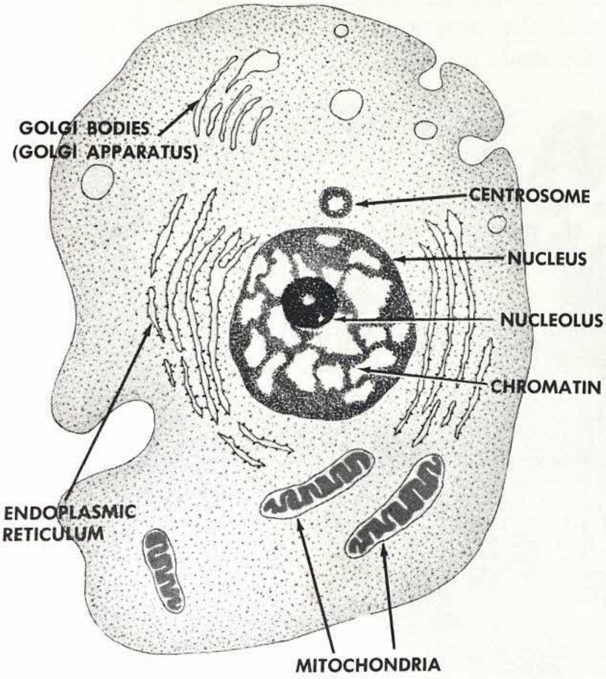
STRUCTURE OF THE BODY

by Mac. V. Edds, Jr.

The human body is an amazingly intricate structure. There are surface details such as the facial features, the hair, and the nails. There are also many meters of intestines, many kilometers of nerves, over two hundred bones, and countless millions of cells. Yet the body is not a hopeless jumble of unlike parts, joined together in hit-or-miss fashion to form a living being. On the contrary, it represents a striking combination of closely interlinked basic units.

The common substance of which all living creatures are fashioned is called *protoplasm,* from two Greek words meaning "first form." This jellylike substances may be the most complex material in the universe. It is the source of all the bodily activities of living things, large and small.

The cell is the basic structural unit of the body. Below: diagram of a typical cell, showing some of the organelles, or sites, of important events within the cell.



CELLS

The protoplasm of the human body is contained within cells, which are the structural units in the body. Most of these are too tiny to be seen with the naked eye. If fifty cells of average size were laid end to end, they would scarcely spread across the period at the end of this sentence.

The protoplasm of a cell is divided into two parts: *nucleus* and the *cytoplasm* that surrounds it. A thin, slightly elastic membrane forms the outer surface of the cell. A similar membrane, which is called the nuclear membrane, separates the nucleus from the cytoplasm.

The nucleus is generally round or egg-shaped. It contains one or more dark round bodies, known as *nucleoli,* and a number of extremely fine, slender threads bearing many irregular granules along their surfaces. These threads are the *chromosomes.* The factors of heredity – the *genes* – are located in the chromosomes.

With the exception of the reproductive cells, every true cell in a given living creature has the same kind and number of chromosomes. In each human cell, except for the reproductive cells, the number is 46. Each mature reproductive cell has 23 chromosomes. The part that such cells play is discussed elsewhere in this set.

Living cytoplasm is a watery fluid in which various chemical substances, such as proteins, fats, and salts, are dissolved. Cytoplasm is not just a structureless solution, however. The molecules of which it consists are arranged in granules, threads, and other structures, all so small that only the electron microscope can reveal them clearly. These tiny structures within the cell are called the cellular *organelles.* They are the sites of all-important events, such as the controlled release of energy from nutrients and the manufacture of new compounds on which growth depends.

The cytoplasm also contains certain

nonliving substances, which range from small, clear fat droplets to fine grains of pigment. In certain cases, bacteria and other foreign particles may be seen in the cytoplasm. Often they are undergoing slow digestion.

There are many millions of millions of cells in your body. The red blood cells alone number about twenty-five million million. And yet each one of us originated as a single cell—a fertilized egg. From this egg, all our cells were then derived by a process of *cleavage*, or division.

Cell division is a relatively complicated process, but we can give its essentials quite simply. During the normal life of a cell, there comes a time when each of the chromosome threads splits lengthwise into two. Each resulting daughter chromosome is an exact replica of the original. When all the chromosomes in a nucleus have split, the cell has twice 46, or 92, chromosomes. These new threads, or daughter chromosomes, now begin to coil up like spiral springs. They finally become so tightly coiled that they resemble small, very dense rods. Then the cytoplasm of the cell starts to pinch in half. As the halves pull apart, each receives one of the daughter chromosomes that arose from the splitting of the original 46 chromosomes. After the division, the tightly spiraled threads uncoil again. Now there are two daughter cells that are precisely like the mother cell.

This type of cell division is known as mitosis. It is of great importance in the growth and development of the body and in maintenance and repair when the body is full grown. Cells are continually dying and being replaced in our bodies. Thousands of dead cells are washed from the surface of the skin every time we bathe. It has been estimated that during every second of our life, 10,000,000 red blood cells die and are replaced by new ones. For a detailed discussion of cell structure, function, and division, see the article "Cell" in *The New Book of Popular Science*.

We have been speaking of cells in a general way, as though they were all alike. As a matter of fact, they differ as widely as do the bodily structures in which they are found. A muscle cell, for example, is especially adapted to contract and produce movement; a kidney cell, to assist in producing and excreting urine.

TISSUES

Similar cells are grouped together in a regular fashion to form tissues. Muscle is one type of tissue. It consists of thousands of fine filaments or fibers piled up side by side. Each fiber is a muscle cell. While it is true that any tissue is made up primarily of a single cell type, other types are also usually present. Thus cells of connective tissue, loosely arranged, penetrate the spaces in and around the muscle cells and hold them together. Connective tissue knits various other body tissues into working units.

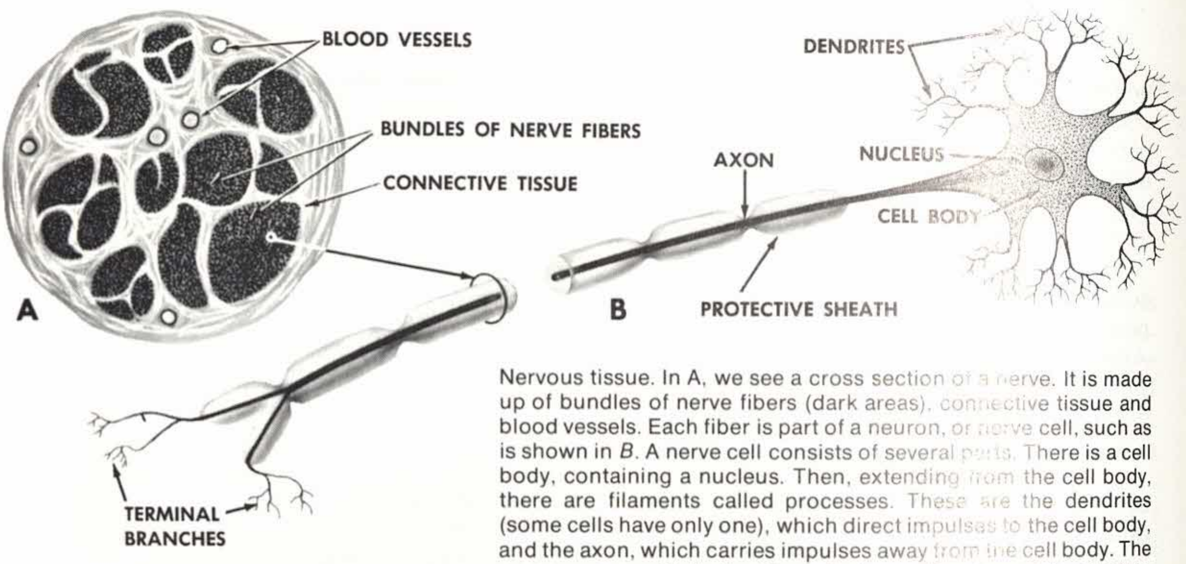
There are four main kinds of tissues. These are: (1) the protective, or lining, tissues that cover the outer surface of the body and line certain internal organs; (2) the muscular, or contractile, tissues; (3) the connective and supporting tissues; and (4) the conducting, or nervous, tissues.

Epithelium. The protective, or lining, tissue is commonly called *epithelium*. Its cells are called *epithelial cells*. Some are flat, others are like cubes, and still others are cylindrical in form. The outer part of the skin, for instance, consists of layer upon layer of flattened epithelial cells. In the digestive tract, the epithelial cells are mostly in the form of tall cylinders.

The windpipe and parts of the lungs have an inner coating of specially adapted epithelial cells with large numbers of tiny, flexible cilia, or threads, which beat with a whiplike motion sweeping mucus, dust, and foreign matter up into the throat.

Not all epithelial cells form lining tissues. Many of them become modified for quite different functions. For example, various types of glands, from the sweat glands in the skin to those that secrete digestive juices in the stomach, are derived from certain epithelial cells.

Muscle. The second large group of tissues is the muscular type, made up of cells that range from a fraction of a centimeter in length to about 30 centimeters. There are three kinds of muscles. *Smooth*, or *visceral*,



Nervous tissue. In A, we see a cross section of a nerve. It is made up of bundles of nerve fibers (dark areas), connective tissue and blood vessels. Each fiber is part of a neuron, or nerve cell, such as is shown in *B*. A nerve cell consists of several parts. There is a cell body, containing a nucleus. Then, extending from the cell body, there are filaments called processes. These are the dendrites (some cells have only one), which direct impulses to the cell body, and the axon, which carries impulses away from the cell body. The processes constitute the fibers that are often bound together in nerves, such as the one illustrated in *A*.

muscle, is found in the *viscera,* or internal organs, of the body. Smooth muscle is spread in delicate strands and sheets throughout the digestive tract, the urinary and reproductive organs, the blood vessels, the respiratory system, and elsewhere. It provides for movements that are not under our control but are indispensable for the functioning of our bodies.

Skeletal muscle is more familiar to us. As the name indicates, it is attached to and moves the bones of the skeleton. All muscle cells are long, thin filaments. In the long cells of skeletal muscle are found large numbers of filaments called *myofibrils,* which run lengthwise through the cytoplasm. They are marked with alternating dark and light bands.

Cardiac muscle is found in the heart. Here the cells are joined end to end in a continuous branching network instead of being set off as separate units. This arrangement, in which each cell is directly connected with its neighbors, seems to be well adapted for producing the sustained, rhythmic contractions of the heart.

Connective tissue. When we speak of connective tissue, we have in mind a large number of similar cells all embedded in a fluid or solid medium, called a *matrix*. Such diverse things as blood, bones, cartilage, tendons, ligaments, and adipose, or fatty, tissue all fall within this class.

In blood, the cells are the *red* and *white blood cells*. The matrix in which they are contained is the fluid *blood plasma*. In cartilage and bone, the cells are trapped in more solid substances. The matrix of bone is hard because of the presence of large amounts of calcium salts, which give bone its solidity and strength. If the salts are dissolved from a dead bone or are lost during life as a result of improper nutrition, the bone loses its strength, becomes supple, and can be bent.

The soft connective tissues are composed primarily of irregularly star-shaped cells within a semifluid substance. In addition, fine fibers run through the matrix, making it denser and stronger. The strength and elasticity of loose connective tissue is dependent on these fibers. The skin, for instance, is firmly attached to underlying structures by bands of loose connective tissue.

Nervous tissue. The conducting, or nervous, tissues are found in the brain and spinal cord as well as in the nerves that connect these organs with the rest of the body. A nerve cell consists of two elements. One of these is the cell body, a tiny irregular mass of cytoplasm containing the nucleus, several granules, and many extremely fine fibrils. The second element is generally made up of one or more filaments of cytoplasm extending out from the cell body. One type of filament carries impulses away from the cell body to some other cell. Another type directs impulses into the cell body. Some of these filaments are almost unbelievably long—about one meter in length.

ORGANS

Just as the cells are grouped to make tissues, tissues are combined to form still larger and more complex units, the organs—the stomach, the intestines, the trachea, the kidney, the spleen, the liver, the heart, and others.

Let us consider an example. The organ that is called the stomach breaks down the food we eat into simpler compounds, which the body can use. The mechanical action of the stomach is made possible by its strong muscular walls. As they contract, anything within the stomach is churned and broken up. Three layers of smooth muscle make up most of the thickness of the stomach wall. One layer runs circularly around the organ, another layer is arranged lengthwise, and the third is oblique. Thus, each layer of muscle produces its effect in a different plane, and the total pattern of movement is highly effective for churning and mixing food particles.

The epithelial cells that line the digestive tract have already been mentioned. The inner surface of the stomach is thrown into folds, and over these the epithelial covering is fitted like a glove over the fingers. In the deep grooves that lie between the folds, different glands are developed from the epithelium. These glands secrete the various digestive juices that assist in the chemical breakdown of food.

Nerve fibers and blood vessels penetrate the stomach along its outer surface and branch into a rich network within its wall. Finally, there is connective tissue.

In some organs—the stomach, for example—muscular tissue predominates. In others, like the kidney or liver, special epithelial tissues make up the bulk of the organ. In the brain, nervous tissue is naturally the most important element. The trachea is an example of an organ where connective tissue is predominant.

SYSTEMS

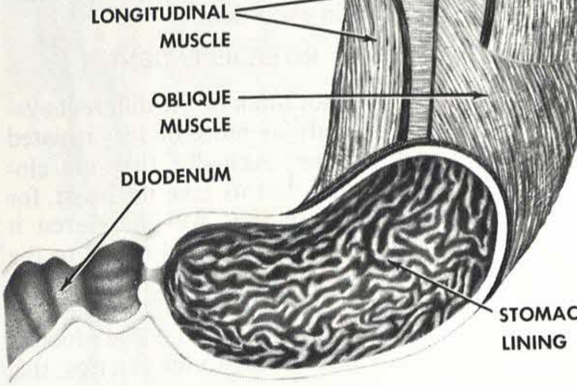
Organs are grouped together to form systems. Thus the digestive system includes the mouth and throat cavities, the esophagus, the stomach, the small and large intestines, and the rectum. These organs all contribute to the same general function: digesting and assimilating food. Each organ in the system is a link in the chain. If it fails, or falters, the whole process of digestion is handicapped to some degree, if not actually prevented.

The body systems include the skeletal, muscular, circulatory, digestive, respiratory, excretory, lymphatic, endocrine, nervous, urogenital, and integumentary.

In the *skeletal system,* the bones serve as a framework for the body and protect internal organs. They manufacture red blood cells in the marrow of long bones. They store calcium, which is supplied at intervals to the blood.

The *muscular system* accounts for all

The stomach contains mostly muscular tissue, but also some epithelial tissue, connective tissue, and nervous tissue.



motion in the body, as the muscles that make up the system contract and relax.

The *circulatory system* carries blood to every part of the body. It consists of a pump – the heart – and a system of "pipes" – blood vessels.

The *digestive system* subjects the food we eat to a series of physical and chemical changes. These make available to the tissues the nutrients contained in the food.

In the *respiratory system,* oxygen passes to the lungs through the process of inhalation and is absorbed by the blood. Waste products – carbon dioxide and water – are carried by the blood to the lungs, from which they are expelled as we exhale.

In the *excretory system* wastes are extracted from the blood and are then passed out of the body in the urine.

The *lymphatic system* is made up of a series of ducts. Through these flows a liquid called *lymph,* which ultimately passes into two large veins.

The *endocrine system* consists of a group of glands, which empty their body-regulating secretions called *hormones,* into the bloodstream.

In the *nervous system* of the body, impulses are carried by nerves to and from the central nervous system.

The *urogenital system* includes the urinary organs and the organs of reproduction.

The *integumentary system* is made up of the skin, hair, and nails (derived from the skin) and the structures associated with the skin. This system protects the underlying tissues, acts as a sensory organ, and plays an important part in regulating body temperature and in excretion.

ALL CLOSELY INTERDEPENDENT

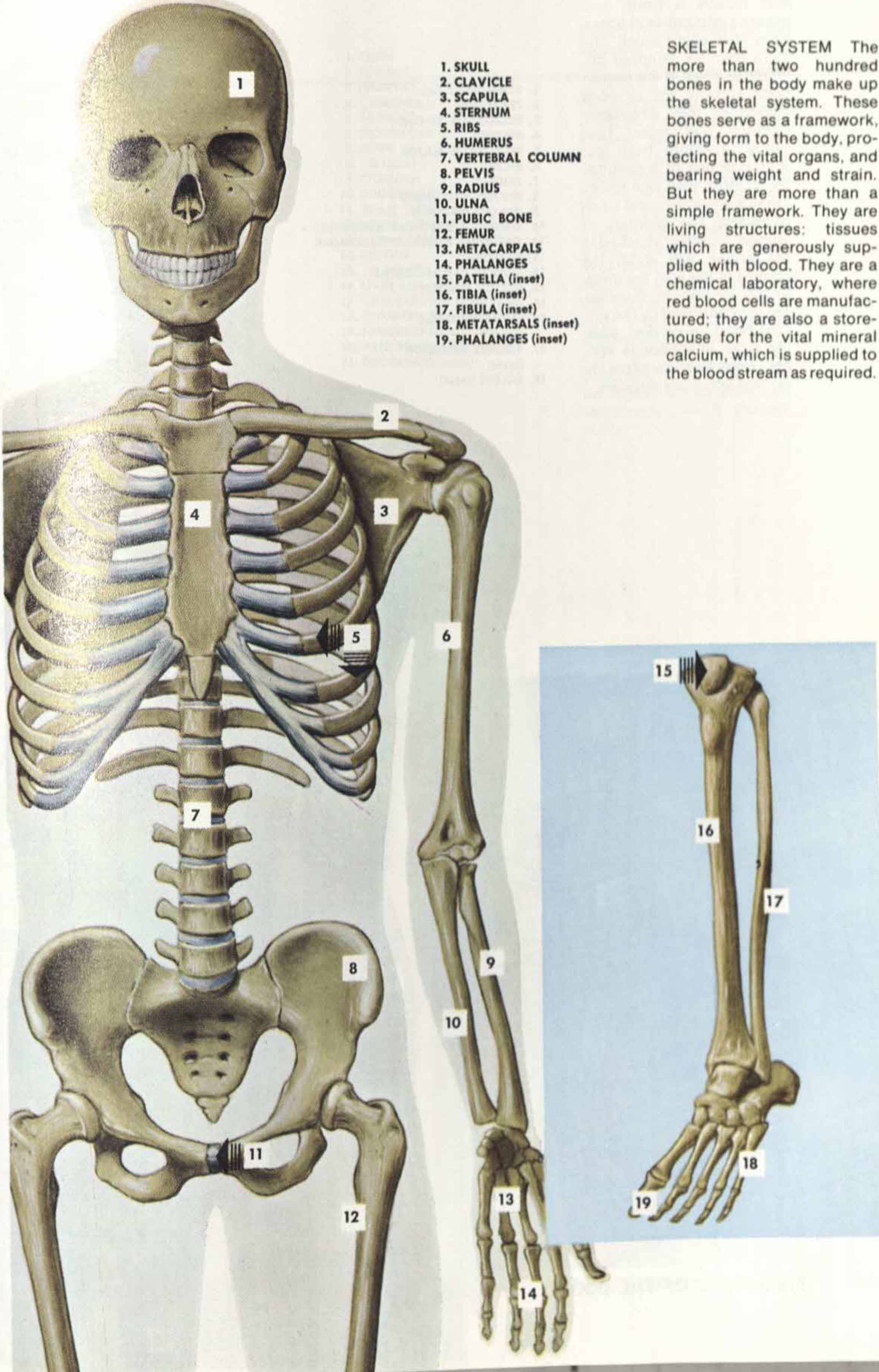
We must not think of the different systems of the body as more or less isolated from one another. Actually, they are closely interrelated. Let us take the heart, for example. Suppose that we considered it only as a pumping organ belonging to the circulatory system. We would want to know something about the mechanics of circulation. We would find out that blood is pumped from the heart to the arteries; that it makes its way to the capillaries and returns to the heart by way of the veins; that it passes from the heart to the lungs and is then returned to the heart; that the cycle is renewed as blood is once more pumped through the arteries. This kind of information would give us a very sketchy idea of the heart and its functioning.

For one thing, to realize what an important part it plays, we would have to know about the fluid that it pumps. We would learn that this fluid, the blood, plays a vital part in resistance to disease and in maintaining a fairly constant temperature in the body. We would learn, too, that it serves to transport oxygen. We would then find out how closely the respiratory system is linked to the circulatory system. For when the blood is pumped to the lungs from the heart, it absorbs the oxygen that we draw into the lungs whenever we inhale. After this oxygen-enriched blood is returned to the heart, it is pumped by way of the arteries and capillaries to the cells of the body. The blood also transports nutrients which have passed into it from the digestive system, and these nutrients also pass to the cells. Here they combine chemically with the oxygen that had been carried in the blood stream. The process of combustion, or internal respiration, then takes place. It is a source of heat and energy.

The blood pumped by the heart is also intimately connected with the endocrine system. The endocrine glands pour out into the blood stream the hormones that regulate the activities of the body. The skeletal system also plays a part in the activities of the blood, for its stores calcium, which is released to the blood.

We would have to consider, likewise, the heart in relation to the muscular system of the body. We would learn how the cardiac muscle – the muscle of the heart – works. We would have to take into account that action of the nervous system as it affects the heart. We would have to analyze the functioning of the cardiac nerves, or nerves of the heart. We would come to realize that there is not a single system in the body that is not connected with the circulatory system and its pump, the heart.

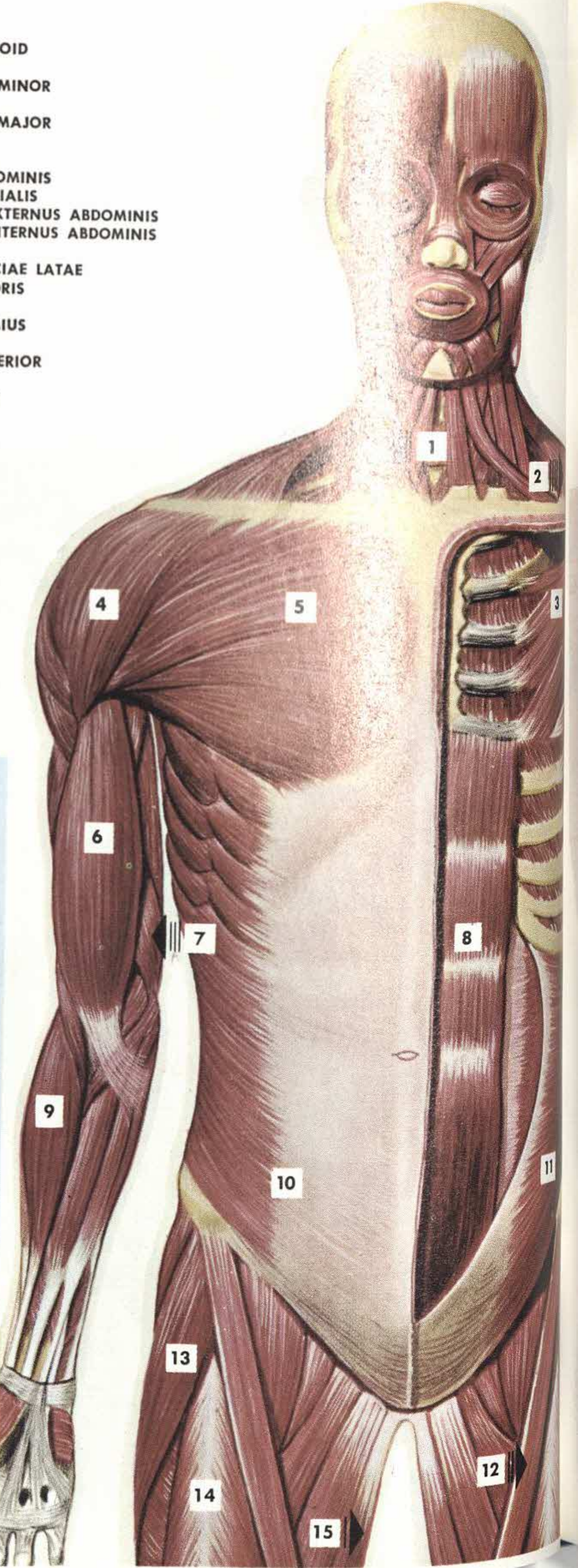
SKELETAL SYSTEM The more than two hundred bones in the body make up the skeletal system. These bones serve as a framework, giving form to the body, protecting the vital organs, and bearing weight and strain. But they are more than a simple framework. They are living structures: tissues which are generously supplied with blood. They are a chemical laboratory, where red blood cells are manufactured; they are also a storehouse for the vital mineral calcium, which is supplied to the blood stream as required.

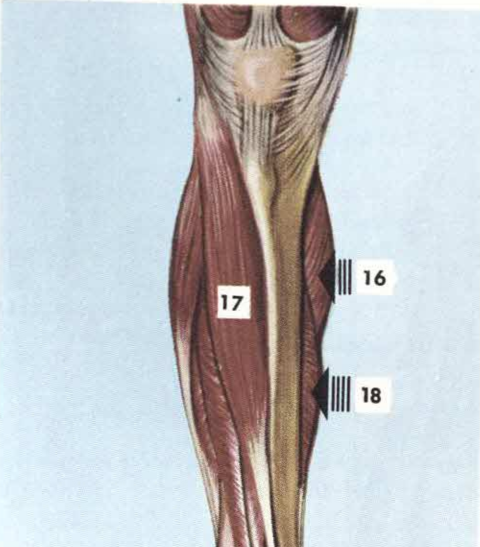


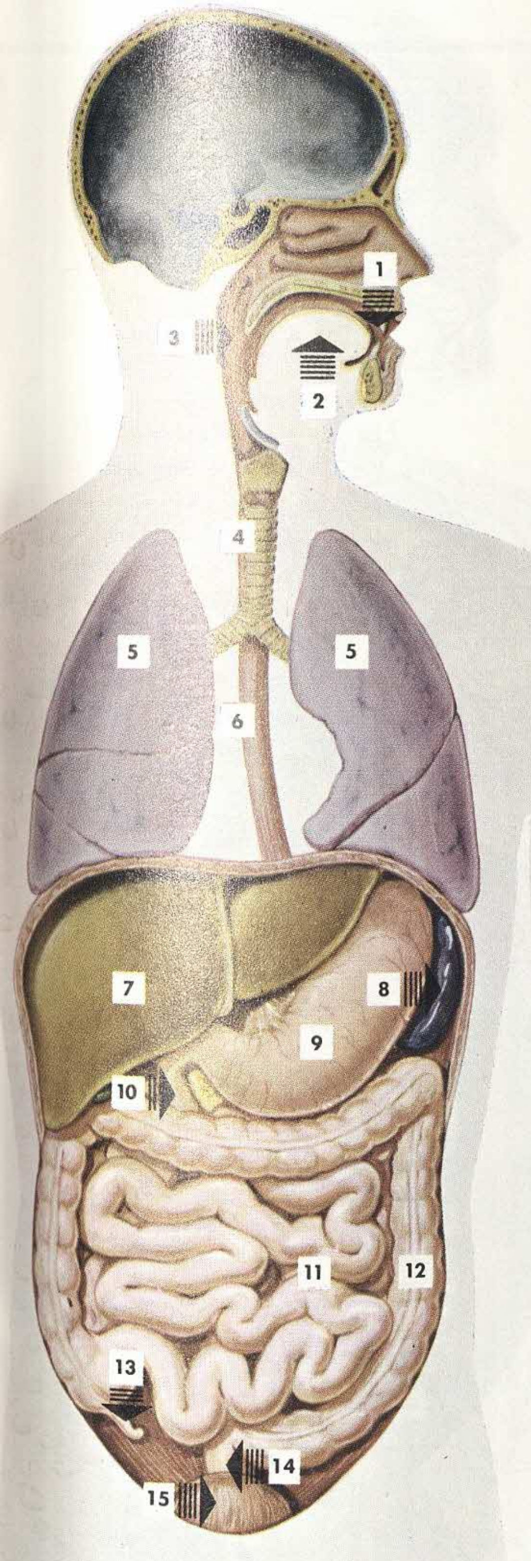
1. SKULL
2. CLAVICLE
3. SCAPULA
4. STERNUM
5. RIBS
6. HUMERUS
7. VERTEBRAL COLUMN
8. PELVIS
9. RADIUS
10. ULNA
11. PUBIC BONE
12. FEMUR
13. METACARPALS
14. PHALANGES
15. PATELLA (inset)
16. TIBIA (inset)
17. FIBULA (inset)
18. METATARSALS (inset)
19. PHALANGES (inset)

MUSCULAR SYSTEM Human muscle is flesh; it is made up of bundles of fibers, each fiber being a cell. The more than six hundred different muscles in the human body account for all body motion as they alternately contract and relax. They range in length from less than one half of a centimeter to more than one meter. There are two principal kinds of muscle. The voluntary, or striped, muscles, attached to the bones, are under the control of the will; the involuntary, or smooth, muscles, are not controlled by the will. (The heart, or cardiac, muscle is an intermediate variety.) Here we show some important voluntary muscles.

1. **STERNOMASTOID**
2. **TRAPEZIUS**
3. **PECTORALIS MINOR**
4. **DELTOID**
5. **PECTORALIS MAJOR**
6. **BICEPS**
7. **TRICEPS**
8. **RECTUS ABDOMINIS**
9. **BRACHIORADIALIS**
10. **OBLIQUUS EXTERNUS ABDOMINIS**
11. **OBLIQUUS INTERNUS ABDOMINIS**
12. **SARTORIUS**
13. **TENSOR FASCIAE LATAE**
14. **RECTUS FEMORIS**
15. **GRACILIS**
16. **GASTROCNEMIUS (inset)**
17. **TIBIALIS ANTERIOR (inset)**
18. **SOLEUS (inset)**

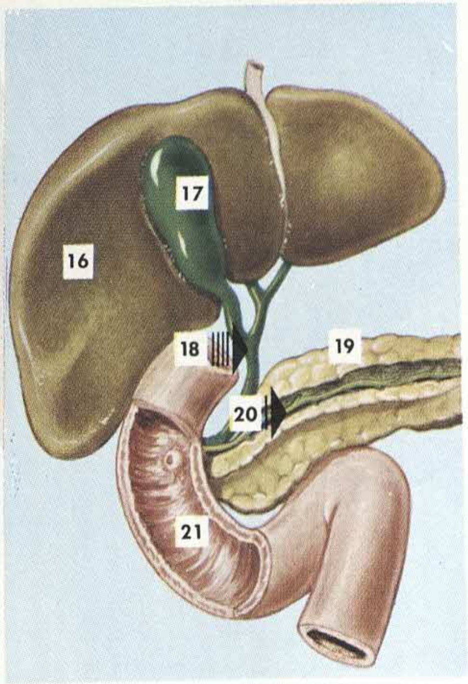






1. **TEETH**
2. **TONGUE**
3. **PHARYNX**
4. **[TRACHEA]**
5. **[LUNGS]**
6. **ESOPHAGUS**
7. **LIVER**
8. **[SPLEEN]**
9. **STOMACH**
10. **DUODENUM**
11. **SMALL INTESTINE**
12. **LARGE INTESTINE**
13. **VERMIFORM APPENDIX**
14. **RECTUM**
15. **[BLADDER]**
16. **LIVER (inset)**
17. **GALL BLADDER (inset)**
18. **COMMON BILE DUCT (inset)**
19. **PANCREAS (inset)**
20. **PANCREATIC DUCT (inset)**
21. **DUODENUM (inset)**

DIGESTIVE SYSTEM In the digestive system, the food that is taken into the body undergoes a series of physical and chemical changes, gives up its nutrients to the tissues, and then is discharged as waste matter (feces) from the body. In the course of these transformations, the food passes through the digestive tract, a long tube that is expanded in certain places. The tube is made up of the esophagus, the stomach, the small and large intestine, the rectum, and the anus. Certain glands, such as the liver and the pancreas, located outside of the digestive tract, pour their secretions into it through ducts.

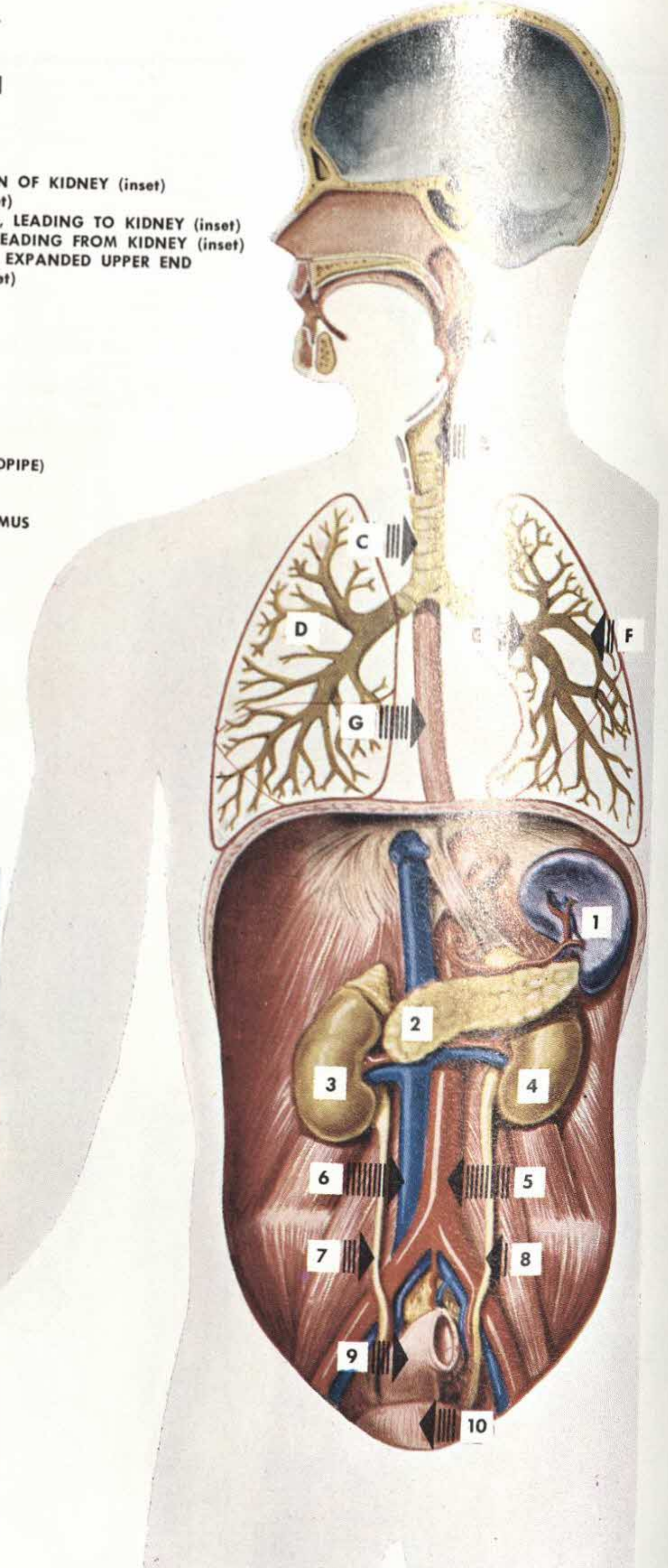


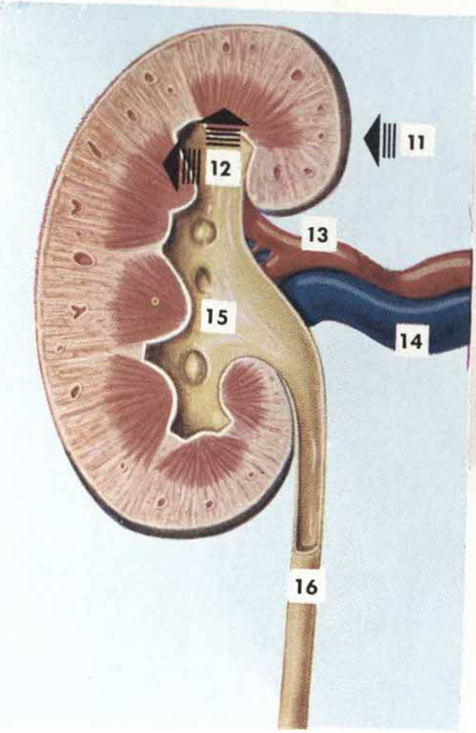
EXCRETORY SYSTEM In the excretory system, wastes are extracted from the circulating body fluid. The kidneys are the chief organs involved. They extract from the blood the waste product urea; this is carried in the fluid called urine from the kidneys to the bladder by way of the ureters. Urine is emptied from the bladder at certain intervals.

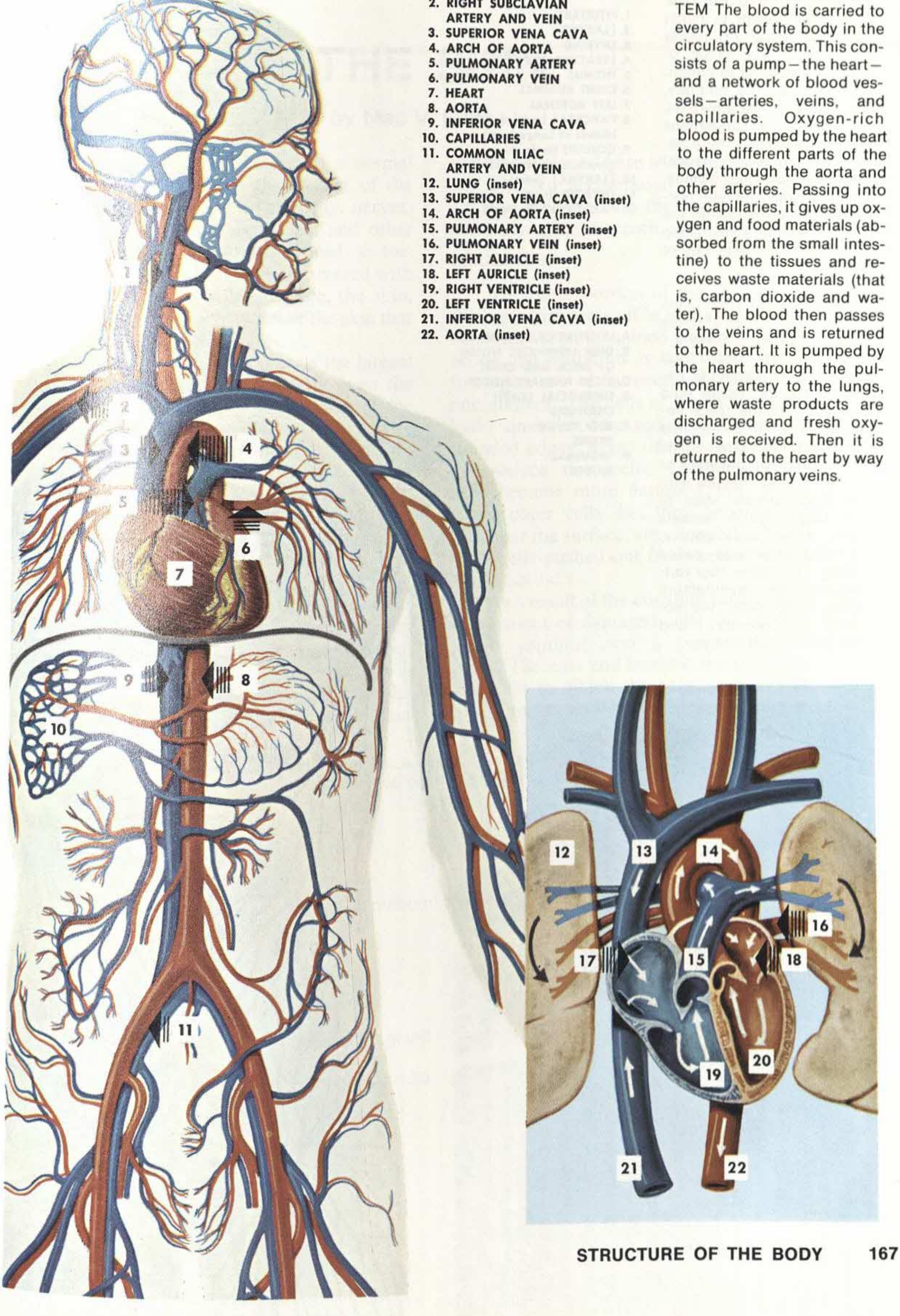
RESPIRATORY SYSTEM Oxygen, drawn in when we inhale, passes by way of the pharynx, larynx, trachea, and bronchi to the lungs. It is absorbed by the red blood cells as blood passes through the lungs. The oxygen is then carried in the blood to the cells, where food material is oxidized and the waste products carbon dioxide and water are formed. The latter products are transported in the blood to the lungs, and are expelled when we exhale.

1. [SPLEEN]
2. [PANCREAS]
3. RIGHT KIDNEY
4. LEFT KIDNEY
5. [AORTA]
6. [VENA CAVA]
7. RIGHT URETER
8. LEFT URETER
9. [RECTUM]
10. BLADDER
11. CROSS SECTION OF KIDNEY (inset)
12. PYRAMIDS (inset)
13. RENAL ARTERY, LEADING TO KIDNEY (inset)
14. RENAL VEIN, LEADING FROM KIDNEY (inset)
15. RENAL PELVIS, EXPANDED UPPER END OF URETER (inset)
16. URETER (inset)

A. PHARYNX
B. LARYNX
C. TRACHEA (WINDPIPE)
D. LUNG
E. BRONCHUS
F. BRONCHIAL RAMUS
G. [ESOPHAGUS]







1. **INTERNAL JUGULAR VEIN**
2. **RIGHT SUBCLAVIAN ARTERY AND VEIN**
3. **SUPERIOR VENA CAVA**
4. **ARCH OF AORTA**
5. **PULMONARY ARTERY**
6. **PULMONARY VEIN**
7. **HEART**
8. **AORTA**
9. **INFERIOR VENA CAVA**
10. **CAPILLARIES**
11. **COMMON ILIAC ARTERY AND VEIN**
12. **LUNG (inset)**
13. **SUPERIOR VENA CAVA (inset)**
14. **ARCH OF AORTA (inset)**
15. **PULMONARY ARTERY (inset)**
16. **PULMONARY VEIN (inset)**
17. **RIGHT AURICLE (inset)**
18. **LEFT AURICLE (inset)**
19. **RIGHT VENTRICLE (inset)**
20. **LEFT VENTRICLE (inset)**
21. **INFERIOR VENA CAVA (inset)**
22. **AORTA (inset)**

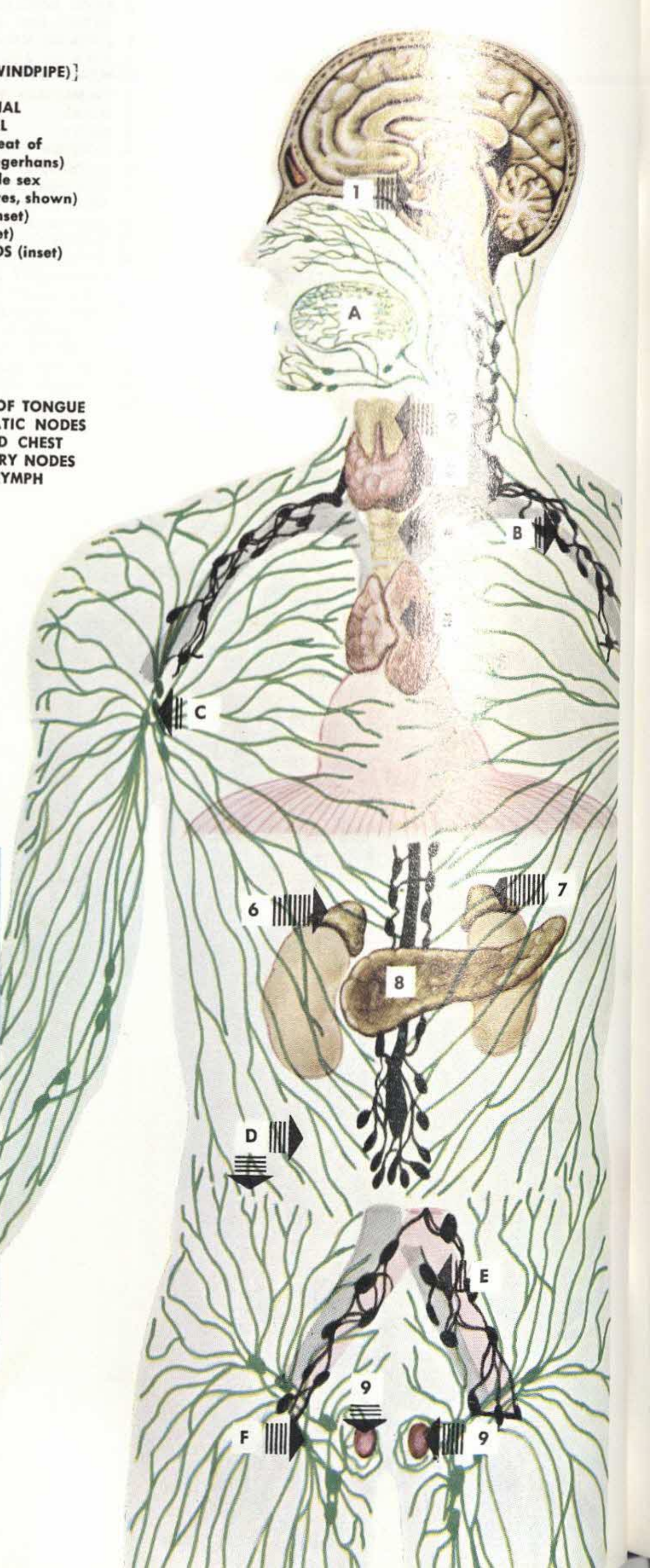
THE CIRCULATORY SYSTEM The blood is carried to every part of the body in the circulatory system. This consists of a pump—the heart—and a network of blood vessels—arteries, veins, and capillaries. Oxygen-rich blood is pumped by the heart to the different parts of the body through the aorta and other arteries. Passing into the capillaries, it gives up oxygen and food materials (absorbed from the small intestine) to the tissues and receives waste materials (that is, carbon dioxide and water). The blood then passes to the veins and is returned to the heart. It is pumped by the heart through the pulmonary artery to the lungs, where waste products are discharged and fresh oxygen is received. Then it is returned to the heart by way of the pulmonary veins.

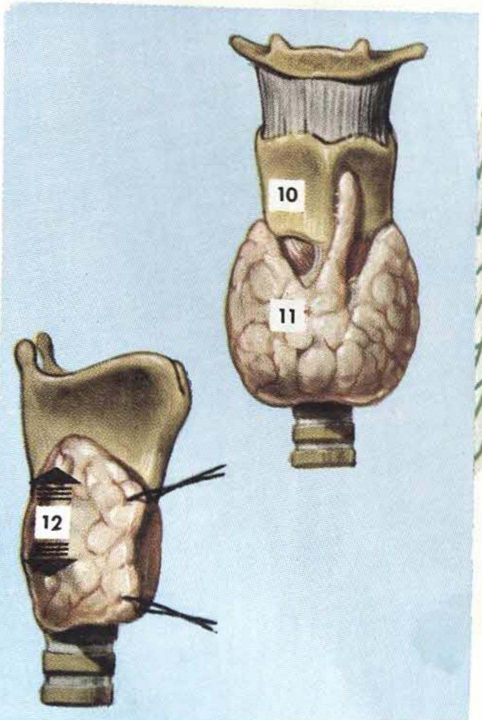
ENDOCRINE SYSTEM The endocrine system is made up of a group of glands called endocrine glands, or glands of internal secretion. They include the pituitary, the thyroid, the parathyroids, the islands of Langerhans (in the pancreas), the adrenals, the gonads (sex glands) and, perhaps, the thymus. These glands secrete hormones, which pass into the blood stream and which help to regulate the activities of the body.

LYMPHATIC SYSTEM This consists of a series of ducts —the lymph vessels— through which flows a fluid called lymph. Lymph is derived from the tissue fluid that occupies the space between cells. It is emptied from the largest ducts in the system into two big veins of the neck and merges with the blood stream. Most of the larger lymph vessels have, along their course, enlarged structures called nodes. The nodes trap various particles, manufacture white blood cells (the so-called lymphocytes), and also produce antibodies.

1. PITUITARY
2. [LARYNX]
3. THYROID
4. [TRACHEA (WINDPIPE)]
5. THYMUS
6. RIGHT ADRENAL
7. LEFT ADRENAL
8. PANCREAS (seat of islands of Langerhans)
9. GONADS (male sex glands, or testes, shown)
10. [LARYNX] (inset)
11. THYROID (inset)
12. PARATHYROIDS (inset)

A. LYMPHATICS OF TONGUE
B. DEEP LYMPHATIC NODES OF NECK AND CHEST
C. RIGHT AXILLARY NODES
D. SUPERFICIAL LYMPH CHANNELS
E. DEEP PELVIC NODES
F. INGUINAL NODES





THE SKIN

by Mac V. Edds, Jr.

The outward appearance of a normal human body can give us no idea of the immense networks of tissues, nerves, bones, blood vessels, muscles, and other structures that extend from head to toe. The reason is that the body is covered with a more or less smooth envelope, the skin, and with certain outgrowths of the skin that we call the hair and the nails.

The skin, or *integument*, is the largest organ in the body, outweighing even the liver. Its surface area, in the case of the normal adult, averages over 20,000 square centimeters. Every square centimeter of skin in most areas of the body contains hundreds of oil glands, sweat glands, and nerve endings, many centimeters of small blood vessels, and many thousands of cells.

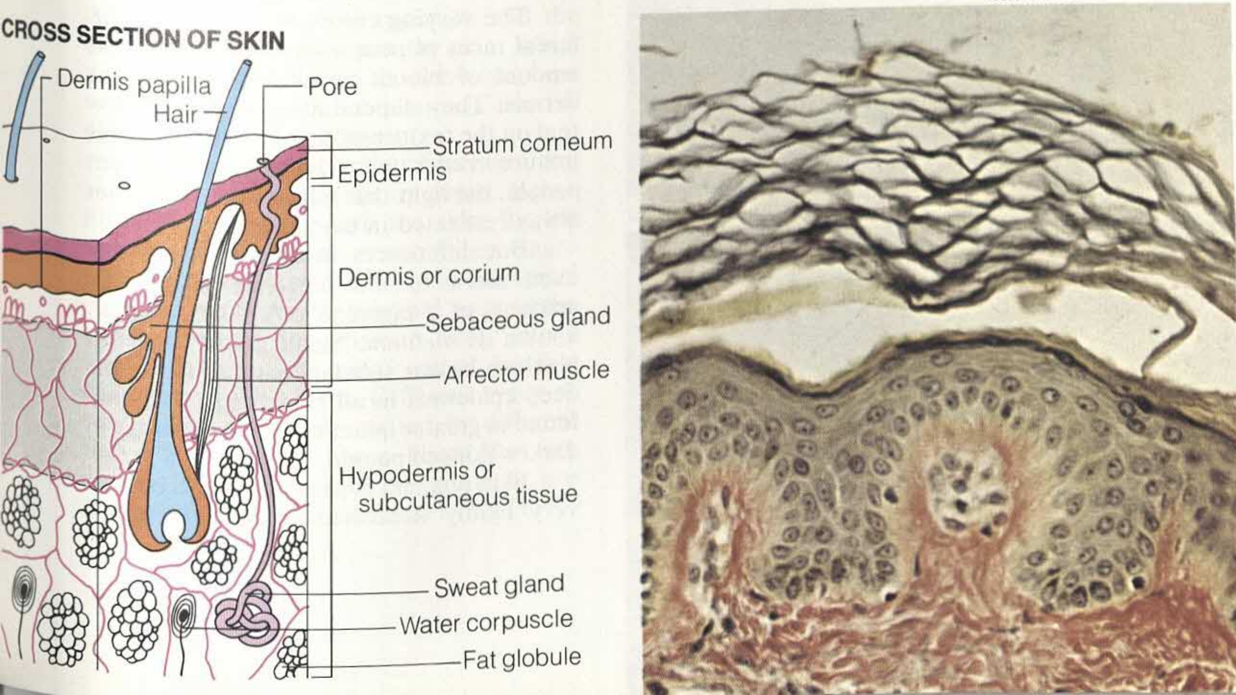
The thickness of the skin ranges from approximately 1/100 of a centimeter to about 1/2 of a centimeter. It is particularly thick in regions that are constantly exposed to friction, like the palms of the hands. Friction is not wholly responsible, however, for the thickness of such areas, because the skin is well developed here at birth.

The skin is composed of two main layers, the *epidermis* on the surface and the *dermis* lying just beneath.

EPIDERMIS

The outer portion of the epidermis is the layer that peels off in thin sheets after a sunburn. When examined under the microscope, the epidermis is seen to consist of row upon row of flattened cells piled upon one another. The cells of the lowest levels look somewhat like squashed cubes with rounded edges. Many of them are dividing to produce new cells. Farther out, the cells become more flattened. As the exposed outer cells die, they become hard and, near the surface, are clumped in flakes. New cells pushed out from below replace the lost cells.

As a result of the constant replacement of worn-out or damaged cells, the skin remains youthful over a period of many years. The cuts and bruises, the burns and scratches to which the skin is always exposed are generally soon healed.



Left: cross section of skin, showing a hair follicle. Right: photomicrograph of skin. Rows of flattened epidermal cells lie atop densely packed dermal cells.

Y. Bruneau/Fotogram

DERMIS

Beneath the epidermis is the second and deeper layer of the skin, the dermis. It consists of a dense network of connective tissue laying under and nourishing the epidermis. Besides being made up of many irregular connective-tissue cells, the dermis contains innumerable microscopic fibers.

There are two kinds of fibers in the dermis. The so-called collagenous fibers are strong and hard to stretch. The dermal fibers of the second type are elastic and enable the skin to adapt itself readily to the changing contours of the body during movement. In old age, these elastic fibers largely disappear and this is one reason why the skin becomes wrinkled. The pattern of wrinkles in the face depends in part on the manner in which the skin has been pulled and stretched by facial muscles.

Unlike the epidermis, the dermis is richly supplied with blood vessels. These provide nourishment, not only for the connective tissue, but also for a variety of glands, nerve endings, muscle cells, and other structures. The boundary between the dermis and the epidermis consists of small, interlocking folds. Nourishment-bearing fluids pass from the dermis to the epidermis through these folds.

The folds along the junction between the two layers of the skin are best developed in areas where it is thick. Over the palm of the hand and the sole of the foot these folds produce a series of ridges and grooves on the surface of the skin. The patterns formed on the fingertips by the arching and looping of the ridges produce the familiar fingerprints. There are so many possible variations of the ridge patterns that no two individuals have ever been found with identical fingerprints. The pattern on each finger tip remains unchanged from infancy to old age. It is so constant that it redevelops in all its detail after the skin is scraped or burned.

There are creases, called *flexure lines*, on the palms. The skin is folded along these creases during hand movements.

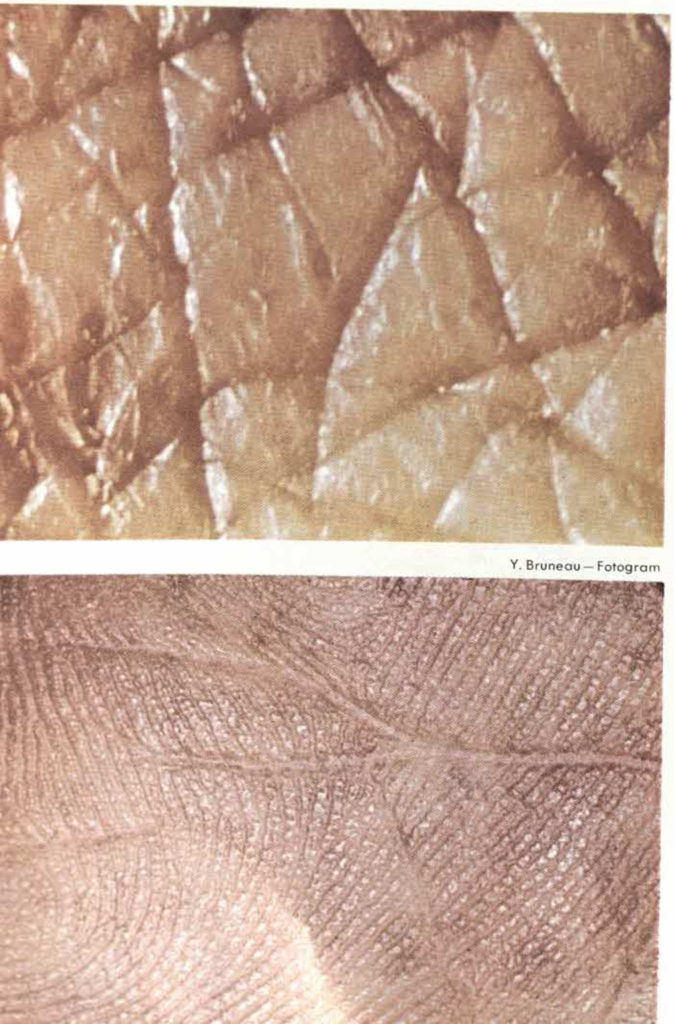
PIGMENTATION

The varying colors in the skins of different races of people depend partly on the amount of blood circulating through the dermis. They depend also to a certain extent on the texture of the dermis. Since this texture varies considerably in different people, the light that falls on the skin is not always reflected in the same way.

But differences in skin tints are due even more to the presence of variable amounts of a pigment, or coloring matter, known as *melanin*. Small granules of this blackish brown substance are found in the deep epidermis in all skin types. They are found in greater quantity in the epidermis of darker-skinned people.

Skin pigment is present at birth but it is very lightly deposited, even in newborn

Skin differs in texture depending on what part of the body it covers. Top: close-up of the skin on the back of the hand. Bottom: the skin on the palm.



Y. Bruneau — Fotogram

Negroid infants. In the latter, however, the skin darkens rapidly and soon attains its characteristic color. The tan that one acquires on exposure to the sun is due in part to an increase of melanin in the epidermis. There are other pigments that contribute to skin color, but these are less important.

FUNCTIONS

One of the most vital functions of the skin is the protection of underlying structures. Since under normal conditions the skin is waterproof, it helps to conserve the water content of the body. Again, since the skin is a poor conductor of light, it shields the rest of the body, within certain limits, from the harmful effects of excessive light. Skin pigments contribute greatly to the effectiveness of the screening process. Natives of tropical countries, where the sunlight is intense, have an unusual abundance of skin pigment for this screening purpose.

The continuous outer layer of the epidermis forms an ideal barrier against bacterial invasions. Being both tough and pliable, it protects the body from minor mechanical injuries. The strength and elasticity of the dermis make it an effective cushion to protect the delicate structures lying within it.

The skin is also vitally important in the regulation of body temperature. When the body becomes overheated, the small blood vessels of the dermis enlarge and carry more blood close to the surface. The blood is then cooled by heat radiation and the evaporation of sweat from the skin. When it becomes necessary to conserve heat within the body, blood channels are reduced and sweating ceases.

In addition to its other functions, the skin serves as a large sensory organ. Nerve fibers extending out into the skin, for the most part, conduct sensory messages from the surface of the body to the spinal cord and brain. At the terminal point in the skin, each fiber may branch freely into a treelike structure, or it may coil up as a fine spiral of varying form. Different types of sensory messages are carried by different nerve fibers. Thus nerve fibers that are excited by painful stimuli, for example, are different from those stimulated by touch.

As a sensory organ, the skin is exceedingly important. Countless stimuli are continually falling on its surface, exciting its nerve endings and sending volleys of impulses on their way to the brain. The awareness that comes to us from these impulses supplements information gained through our other senses. If the nerves to the skin are destroyed, this awareness is lost.

SKIN GLANDS

Sweat glands. The sweat glands of the skin aid in getting rid of certain waste products. The openings of the canals through which the secretions of these glands reach the surface can be seen by examining the fingertips with a magnifying glass. Down the center of each of the ridges, a row of tiny depressions will be found. The canals that open into each depression spiral downward through the epidermis and into the dermis where each connects with a sweat gland.

The gland itself consists of a twisted tube of specialized cells that are able to extract water and other materials from their surroundings. The sweat produced by these glands is largely water. It contains, at most, 1 per cent of dissolved solids, or sodium chloride, and urea. Since salt is excreted when perspiration takes place, it is important to replenish the body's supply of salt by including it in the diet during hot weather.

Ordinarily the kidneys rid the body of 99 per cent of the urea resulting from cell metabolism. But as much as 10 per cent of urea may be carried through the sweat glands when we perspire profusely.

The quantity of sweat produced naturally depends on such things as external temperature, activity, diet, emotion, and state of health. Under average cool conditions, the normal healthy adult secretes about 225 milliliters daily. This quantity may be increased many times by hard labor in the hot sun. There are about two million sweat glands scattered through the dermis in man. Their activity is most pronounced in areas like the hands and feet, face, neck, and armpits. Many animals are not so well provided for. In the dog, for example, only the footpads sweat, and nearly all cooling by evaporation takes place from the lungs and tongue as the animal pants.

Sebaceous glands. A second type of gland, also lodged in the dermis, is the sebaceous, or oil, gland. The sebaceous glands produce the oil that lubricates and waterproofs the skin and lends a gloss to the hair. Of the various regions of the skin, only the soles and palms are free of oil glands. The appearance of these areas after the body has been in water for a long period of time illustrates the importance of skin oil as a waterproofing agent.

HAIR

We come now to the modified kind of skin that we call the hair. One of the things that seems to set man off from other mammals is the small amount of hair over the surface of his body. As a matter of fact, however, the "naked" human skin is really covered with a great many fine hairs. Only a few regions, such as the lips and parts of the hands and feet, are completely hairless. If the human skin appears naked, it is only because the hair is generally inconspicuous.

A baby has hair before it is born. It usually has more hair, in fact, while it is still within the uterus than at birth. At birth, the scalp is often covered with hair, which soon falls out. During the first few months of life a short, downy fuzz appears all over the body. This hair is soon replaced by a coarser type over the scalp and eyebrows. Much later, it is similarly replaced in other regions, such as the armpits. But the downy hair is retained over most of the skin.

When most people use the word "hair," they have in mind scalp hair. This differs considerably among the various peoples of the world in both texture and quantity. The hair of Mongoloid peoples is generally quite straight. In some Negroid types, it is so short and tightly curled that it is almost woolly. There are many gradations between these two extremes. The degree of curliness depends in part on the shape imparted to each shaft of hair as it grows. The shape depends on the configuration of the protein *keratin* that makes up the hair.

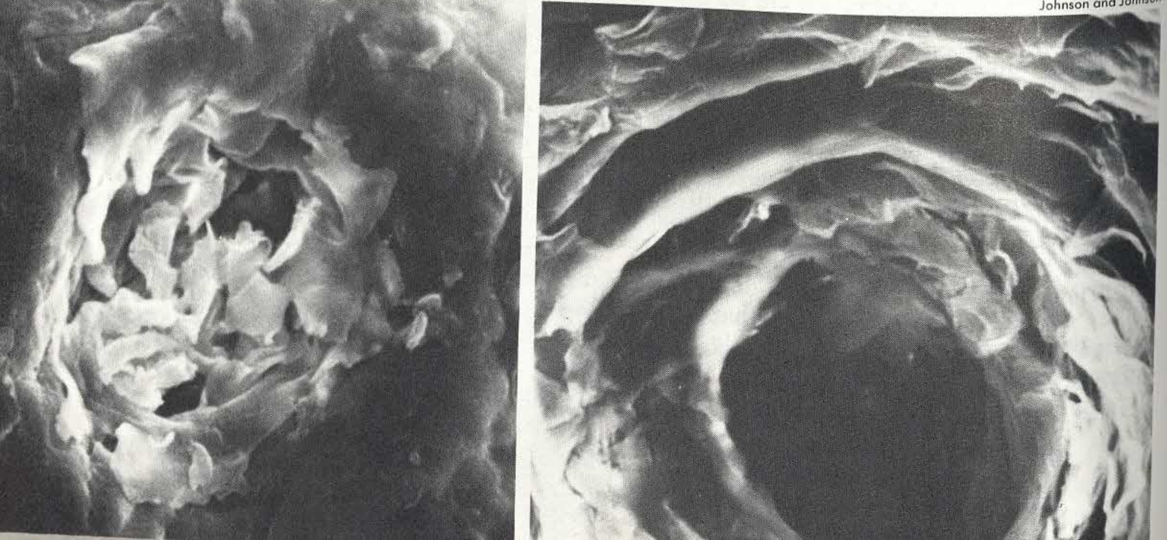
STRUCTURE OF HAIR

The first sign of hair in a developing human being is a little knot of specialized cells lying deep in the epidermis. These cells multiply rapidly and push down into the dermis to form a slender rod of tissue. Thus begins the formation of the *follicle*, the depression in the skin from which the hair grows. At the inner end of the rod of tissue, a cup-shaped bulb is fashioned.

The cells lining the interior of this bulb now begin to form the *hair shaft*. They continue to multiply actively. Some of them become flattened and tightly packed together. As more and more cells accumulate, they form a *bud* which pushes upward. This

Human sweat pores viewed through a scanning electron microscope. Left: the pore is clogged by psoriasis, a skin disorder. Right: a normal pore. Sweat glands regulate body temperature by secreting fluids.

Johnson and Johnson



bud is the hair shaft. It is made up of hundreds of flat, horny cells so closely packed that the individual elements can hardly be recognized. The cells of the hair, like those of the other epidermis, are gradually dying as they move farther from their source of nourishment.

Finally the shaft pushes through and beyond the surface of the skin. The growth center at the base of the follicle remains active. As new cells are packed into the base of the hair shaft, its outer end continues to extend farther and farther from the surface of the skin. Clearly, the growth of a hair depends entirely on its follicle. If the latter is destroyed, the hair that arose from it is gone for good.

A varying amount of brownish black pigment is loaded into the hair shaft as it grows. This is the same melanin that is found in the epidermis. The amount of pigment that is present naturally determines the actual color of the hair. As people age, the center of the hair shaft changes and it tends to become filled with minute air bubbles, which make the hair appear gray or white. Air enters the hair only in the region where it is actually growing, at the base of the follicle, and it takes time for the air-filled part of the hair shaft to reach the surface of the skin. That is why it is difficult to believe accounts of the hair turning gray overnight as a result of some emotional strain.

The hair shaft consists of two layers built up around a central core. The outermost layer is the *cuticle*. Its flat, four-sided cells overlie one another like shingles on a roof. The second layer makes up the bulk of the hair shaft. Its cells are so arranged that they give the hair maximum strength and flexibility. The cells of the central core are shrunken and separated by numerous spaces. This *core* is not always present in the hair shaft, particularly in the case of hairs far thinner than the average.

GROWTH OF HAIR

The life of human hairs is limited. Most of them probably drop out after two or three years, though some may last as long as six years. In many animals the hair is shed every year during the approach of warm weather and it grows again in preparation for winter. Certain hairs—for example, those in the tail of a horse—appear to last as long as the animal lives.

When a hair drops out or is rubbed off, its follicle does not always die as a consequence. On the contrary, it generally persists and begins to fashion a new hair shaft. Each individual hair goes through a life cycle of its own. There is a period of youth when it grows rapidly. Then, there is an interval during which its growth is not so marked. Finally the hair stops growing and is shed. Over any particular area of the scalp, about 90 per cent of the hairs will be actively elongating at a given time.

Contrary to popular belief, the rate at which hairs elongate is not increased by shaving them. It is true, however, that hair grows more quickly in the summer than in winter and more slowly at night than during the day. The normal rate of hair growth may be maintained even though various other tissues of the body have been severely affected by a condition of prolonged malnutrition.

There is a curious superstition that the hair keeps on growing even after death. This belief is a mistaken one. As we have seen, the extension of a hair from its follicle is a vital process depending on the activities of the living cells at its base. When a hair follicle is deprived of its blood supply at death, its cells die and no further growth can possibly occur. It is true, however, that the hair present at death may become somewhat more conspicuous as the skin of the corpse shrinks.

Many hairs can be moved slightly. A small pimple arises at the place where the hair emerges from the surface of the skin. The shaft itself no longer lies flat but stands upright. This condition, known as "goose flesh" or "goose pimples," is caused by cold (sometimes by fear). The movement of the hair shaft is produced by smooth muscle cells, a few of which are attached to the side of each hair follicle. In the vertical position, the hairs serve to keep a thicker layer of stagnant air about the body, and this provides added protection against cold, since air is a good insulator. Since man has lost most of his body hair, the added protection does not amount to much.

The hair is lubricated and made glossy by secretions that frequently pour out from the oil glands through the hair follicles. If it were not for this homemade lubricant, the hair would be brittle.

HAIR LOSS

Some people suffer a partial or total loss of hair—the familiar condition known as *baldness*. There are several kinds of baldness. In some cases, it does not seem to be due to any disease; the victim simply finds that his hair is growing thinner at the crown of his head or at the temples. At last, the follicles will not produce any more hairs and the skin is left bare.

In other cases, loss of hair is due to a diseased condition. The most striking symptom is generally a scaly dandruff. This may be caused by any one of a number of ailments. Dandruff continues to appear while the hair is falling out, and it disappears when the hair is all gone.

There is no sure cure for baldness. However, it may be checked by skillfull professional treatment.

NAILS

Like the hair, the nails are nothing more than modified skin. The tips of the fingers and toes of a young human embryo are covered only with skin. At the end of the third month of embryonic life, this skin starts to change and it is gradually converted into nails. When the nail first begins to form, it lies beneath the horny outer layer of the epidermis. This outer layer usually disappears before birth, but part of it remains as the cuticle at the base of each nail.

Two areas are easily visible in a well developed nail. The larger part is pink, due to the rich blood supply of the underlying dermis. Behind the pink region is a pale whitish area known as the *lunula*. All the growth that constantly pushes the nail forward takes place beneath the lunula. The remainder of the nail merely slides along passively.

The tissue under the nail is called the *nail bed*. It is actually a direct continuation of the deep, actively growing layer of the epidermis. As we just noted, the tissue under the pink area of the nail contributes nothing to it and serves merely as a smooth surface on which the nail glides forward. However, the portion of the nail bed beneath the lunula presents quite a different picture. Here, the tissue-forming cells are more numerous and are dividing continually. As they increase in number, those closest to the nail root become flattened and are pressed tightly together.

Each cell is gradually transformed into a thin, horny plate. The tiny plates are then piled in lamellae, or layers, which make up the substance of the nail. Nuclei are still visible in the horny cells near the root of the nail, but as the cells are pushed forward, all signs of structure seem to disappear. However, if even the fully formed nail is soaked in caustic soda, it can be broken up into small scales, each representing an original cell containing a nucleus.

The ridges and bumps often seen on a nail result from uneven growth of the nail at its root. Occasionally white, irregular flecks appear in the nail substance. These spots are simply bubbles of air trapped between the cell layers.

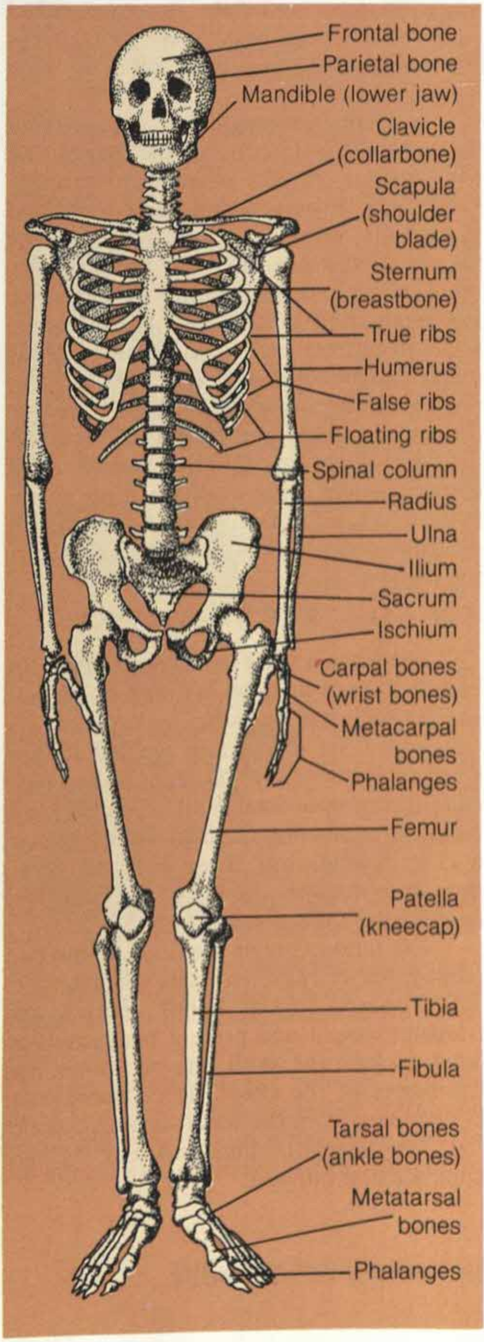
Nails grow at very different rates. Those on the fingers advance about three or four times as rapidly as those on the toes. The fingernails on the longest fingers (the middle fingers) grow quickly; those on the shortest or little fingers, most slowly. There appears to be no significant difference, with respect to growth, between the nails of the right and left hands. In summer, the nails, like the hair, advance faster than in winter. The thumbnail, for instance, grows an average of 0.3 centimeter per month in the winter and 0.4 centimeter in the summer.

The function of human nails is not clear. Fingernails can be used for scratching. They also provide a mechanical support for the tips of the fingers, and they help us to manipulate certain thin objects, such as needles. But human toenails, as far as we can see, serve no useful purpose, though they may have been useful at one time.

THE BONES OF THE BODY

by H. A. Cates

The major bones of the human skeleton as seen from the front.



Bone is one of the most complex and most versatile of all tissues. It serves as a *skeleton,* or framework, giving form to the body, protecting the vital organs, and bearing weight and strain. It is also a chemical laboratory, where red blood cells are manufactured, and a storehouse for the vital mineral calcium, which is supplied to the blood as it is required. A bone resists pressure and accepts strain: it is hard, yet flexible. It owes these properties to its composition. It is two-thirds mineral matter—largely calcium phosphate—and one-third animal matter—chiefly a gelatinlike, elastic substance known as *collagen.* The hardness of bone is due to its mineral matter; its flexibility is due to its proteins.

Bones are living structures like the other tissues of our body. They generally maintain themselves very efficiently. When they are broken, or fractured, they mend themselves. They are generously supplied with blood for their nourishment. They are also sensitive—as anyone who has suffered a fracture or a bruise can tell.

PARTS OF BONE

During a person's early years, while a bone is still growing, it is not a single unit but is in three pieces. Each end, or cap, is separated from its long shaft by a plate of *cartilage* known as the *growth plate.* As long as this plate persists, the bone continues to grow and to get longer. As it develops, it often changes its shape and appearance. The thighbone of a child, for example, is quite different from that of an adult. During the growing stage, a cap is sometimes knocked off its shaft as a result of a fall or a hard blow. Unless the cap is accurately restored, a serious deformity may result.

The outer surface of all bone is made up of a dense, ivorylike substance known as *compact bone*. It is interlaced with numerous small canals that provide passageways for the nerves and blood vessels that nourish it. These passageways are called *Haversian canals*.

Long bones consist entirely of a hollow shaft of compact bone. The central cavity is filled with fatty tissue called *bone marrow*. In some cases there is an outer covering of compact bone, and inside this outer covering a porous, trellislike structure called *cancellous,* or spongy, *bone*. The spaces left within cancellous bone are filled with bone marrow.

In the ends of long bones and scattered throughout the interior of flat bones and ribs, we see streaks of reddish material. These are manufacturing centers for red blood cells, which transport oxygen to the tissues. If the bone marrow that contains these manufacturing centers is damaged, the production of the cells is inadequate and the sufferer becomes anemic. Certain materials, such as lead and benzol, are injurious to bone marrow. Workers who use these materials to any great extent are particularly likely to develop anemia. This condition may also result when an abnormal growth, or tumor, in the bone marrow destroys some or all of the tissues that form red blood cells.

MANY—EACH WITH ITS OWN ROLE

The human skeleton is made up of 206 bones. These bones are of different size and shape. Each has its particular function.

Bones are not firmly welded to one another. Rather they are connected at their ends by more-or-less flexible joints. Muscles and ligaments, or tough bands of connective tissue, run from bone to bone, serving to connect the bones and allow for movement of the joints.

The human bones are divided into two groups: the *axial skeleton* and the *appendicular skeleton*. Axial bones receive and transmit weight and protect body cavities. They include the skull, the backbone, and the bones of the chest. The appendicular bones hang from the main, or axial, skeleton. The bones of the arms and legs are appendicular bones.

THE AXIAL SKELETON

The axial skeleton includes the skull, the vertebral column, the ribs, and the sternum.

THE SKULL

The skull is the framework of the head. It includes the *cranium*, the protective covering of the brain, and the bones of the face. There are 22 bones in the human skull, 21 of which are so firmly united that movement between them is impossible. One bone, the *mandible*, or lower jaw bone, is hinged to the rest of the skull just in front of the ear opening and is independent and movable.

Cranium. In lower animals such as fishes the cranium, or braincase, is small and relatively insignificant. It lies behind the face, which, projecting forward, is very prominent. In humans, however, the cranium is greatly expanded so that if we look at a human skull from above, no part of the face is visible. The forward expansion of the human cranium has resulted in very deep sockets for the eyes.

The human cranium is composed of eight bones. The *frontal* bone is roughly over the forehead. Two *parietal* bones are at the top and upper sides of the head. Two *temporal* and two *sphenoid* bones are on the lower sides of the head, and the *occipital* bone makes up the back of the skull.

The various skull bones fit into one another like the pieces of jigsaw puzzle. At birth these edges are not yet interlocked but are held together by connective tissue strips called *sutures*. In certain spots, the *sutures* are wide and there are soft spots, called *fontanels*. As a child matures, the sutures fuse, and the bones become completely hard and immovable.

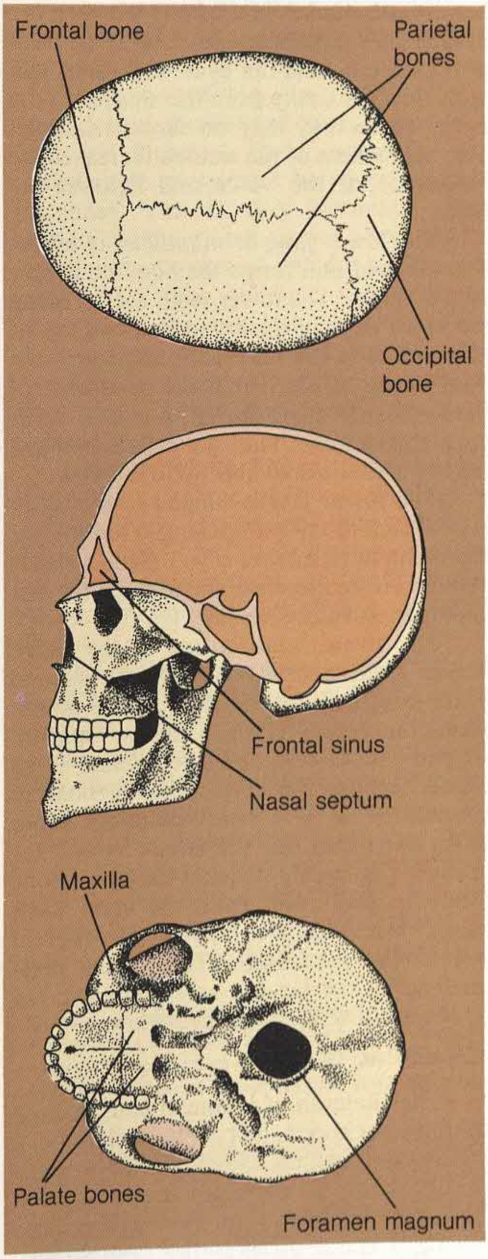
The floor of the cranium is high in front, coming above the eyes, but it slopes rapidly downward. At its lowest point, some distance forward from the back of the head, there is a great hole called, appropriately enough, the *foramen magnum* (Latin for "big hole"). Through it passes the spinal cord, as well as various arteries and nerves.

Facial bones and sensory organ supports. In the middle section of the floor there is a complex system of minute caverns and tunnels in which the delicate organs of hearing and balance are sheltered. In the middle section of the floor we also find numerous small openings for the passage of nerves and blood vessels. Their presence weakens the floor and makes fractures exceedingly serious. In this area the floor roofs the pharynx—the air and food passage at the back of the nose and mouth. Below the very thin forepart of the floor lie not only the eye cavities but also the narrow slitlike upper part of the nasal cavities between them.

The paired *nasal cavities* are separated from the mouth by the palate. This is divided into two sections: the *hard palate,* in front, which is bony and rigid (we can feel it with the tip of our tongue just behind the upper teeth), and the *soft palate,* thin, soft, and movable, lying directly behind it. The movable palate projects backward into the pharynx and by pressing against it shuts off the passage to the nose when we swallow.

Each nasal cavity is separated from its fellow by a partition called the *septum.* The septum is mainly bony in structure, but in front it is made up partly of cartilage. That is why we can twist the tip of the nose. The side wall of each nasal cavity has scroll-like bones projecting from it. These are known as the *shells* (conchae) or *whirlers* (turbinates). Incoming air must make its way through the long curved passages of these bones. In the course of this journey the air is warmed and filtered. Mouth breathers, of course, lose these advantages. In front, the nasal cavities lead to the face by way of the nostrils. Behind, their much larger openings (internal nares or nostrils) lead into the pharynx. From here, the incoming air enters the larynx, or voice box.

The bones of the face are thin and delicate. Those surrounding the nasal cavities contain *sinuses,* or cavities. They are hollowed out till they are but thin shells of bone. Because they all open into the nose and are lined with a continuation of its mucous membrane, they are easily infected from the nose.



Three views of the human skull. Top: as seen from above. Middle: cross-section as seen from the side Bottom: as seen from the bottom, with the mandible removed.

The largest of the sinuses extends along the nose, above the upper teeth, and below the eyes. Another sinus lies deep in the bone above each eye. There are a number of little sinuses in the bone between the eyes and a very inaccessible one at the back of the nose behind the eyes. Infections can spread rather easily from the sinuses to the eyes, where they may do serious damage. The hollowness of the sinuses increases the resonance of the voice and lightens the face.

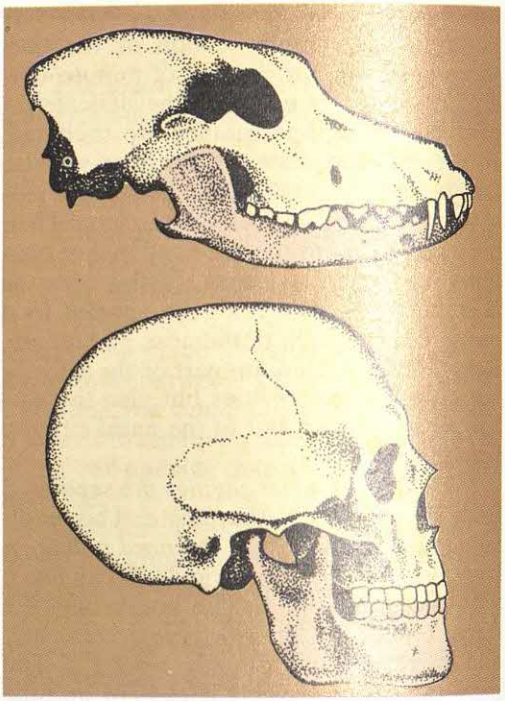
The lower jaw, or *mandible,* is horseshoe-shaped and forms the bony boundary of the mouth. The lower teeth are set along the upper edge of the horseshoe. A sheet of muscle fills in the horseshoe and forms the floor of the mouth. From the open ends of the horseshoe there springs a pair of vertical plates of bone. They are called *rami* and they extend the mandible up to the joint.

The lower jaw is hinged to the skull just in front of the ear opening. You can feel it moving in its socket if you place a finger about two centimeters in front of the ear and open and close the jaw.

The hyoid bone is one of the facial bones. This slender U-shaped bone is found in the angle where the floor of the mouth meets the neck. "Hyoid" means "upsilon-shaped" in Greek; the hyoid bone is so called because the corresponding bone in animals with a forward-pointing snout looks something like the Greek letter Γ, or upsilon. Ligaments suspend the hyoid bone from the skull, and from the bone there hangs the Adam's apple, or thyroid ("shieldlike") cartilage. This is the chief cartilage of the larynx. In swallowing, the larynx is pulled up to the hyoid bone.

VERTEBRAL COLUMN

The skeleton of a human body is built around a backbone, just as the skeleton of a ship is built around a keel. So important is the backbone, or vertebral column, that it serves to divide the animal kingdom into two important groups—the vertebrates, who possess it, and the invertebrates, who do not. Fishes, frogs, reptiles, birds, and mammals are vertebrates. They all have backbones constructed on the same basic plan.



The skull of a dog and of a human being. Note the far larger brain case in man. The dog's long jaws are, in the living animal, worked by strong muscles attached to the sides of the skull. The reduction of these jaw muscles in man may have allowed his braincase to expand.

The keel of a ship must be straight and rigid. It would be most unsatisfactory, however, if man's "keel" were a ramrod of bone running down his back. The vertebral column must have a certain amount of rigidity, indeed, but it must also be flexible so that our backs can twist, turn, and bend. As a matter of fact, vertebral comes from the Latin word *vertere:* to turn. Instead of being a single rod of bone, then, the backbone is made up of a number of small cylindrical blocks. Each of these is fastened to its neighbor by a disk of resilient cartilage, which absorbs shocks and strains. The blocks are called *vertebral bodies,* or *vertebrae.* The disks of cartilage are called *intervertebral disks.* The backbone can sway and bend. At the same time it is rigid enough to support the head and to serve as a place of attachment for the ribs and the hip bones.

Behind our sturdy column of bony blocks lies the delicate spinal cord. It runs through a series of arches of bone—the *neural arches*—each forming part of one of the vertebrae. Within its bony housing, the spinal cord is protected by three layers of membranes. At the sides, between adjacent arches, are large openings called *foramina* through which the spinal nerves make their way to the organs of the body.

The backbone is made up of 33 (sometimes 34) vertebrae. They are usually divided into five main groups. First we have the seven cervical vertebrae in the neck. *Cervix* means neck in Latin. The twelve vertebrae in the chest are called thoracic, from *thorax,* the Greek word for chest. Below the chest there are five lumbar vertebrae, making up the small of the back. After that, there are five sacral vertebrae that are fused into a single bone, the sacrum. The vertebral column ends with the coccyx, a single bone made up of four (sometimes five) vertebrae.

Cervical vertebrae. According to Greek legend, Atlas was a mythical giant who supported the earth on his shoulders. Because the first cervical vertebra supports the head in like fashion, it is called the *atlas*. This is merely a ring of bone broadened at the sides into two concave surfaces on which the head is poised and on which it can rock back and forth in nodding.

The second cervical vertebra is called the *axis* because it has a short, axislike peg of bone projecting upward into the ring of the atlas. Around this peg the head and atlas pivot when the head is shaken.

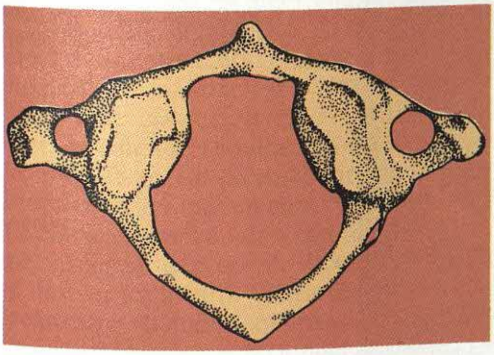
The cervical vertebrae all have thick *intervertebral disks,* allowing the neck to move freely on its bony axis.

Thoracic vertebrae. In the thoracic, or chest, region, the disks of cartilage are quite thin, and therefore there cannot be any considerable movement between adjacent vertebrae. This is very fortunate, since each thoracic vertebra carries a pair of ribs, and undue movement would buckle and break them. The thoracic vertebrae are larger than the cervical vertebrae. The place where the last thoracic vertebra meets the first lumbar vertebra is a critical area, for a broken back most commonly occurs there.

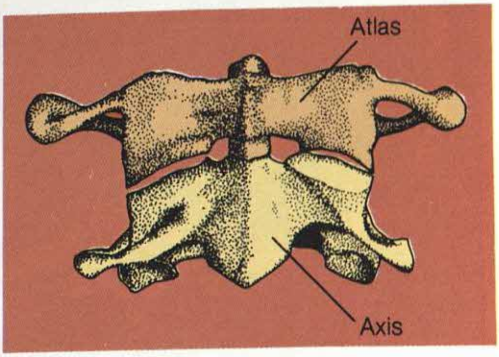
Lower vertebrae. The cartilage disks between the vertebrae of the lumbar region are very thick. Hence the spinal column is most flexible in this region, as anyone who has seen a contortionist can testify. A displaced, or slipped, disk has a crippling effect.

Below the lumbar vertebrae is the large *os sacrum* ("holy bone" in Latin), more commonly known as the *sacrum.* It represents five vertebrae that have been fused. Why should this particular bone be called "holy"? According to one explanation, the Greeks also called the bone the "holy bone" *(osteon hieratikon).* But the word *hieratikon* means not only "holy" but also "unusually large." In this case, therefore, *osteon hieratikon* really meant "large

The atlas, the first of the cervical vertebrae, or neckbones. It is basically a ring of bone, broadened at the sides into two surfaces. The skull articulates, or joins, with the atlas, on which it is made to move back and forth.



The axis, or second vertebra of the neck, articulates with the atlas above. The latter surrounds the upward-projecting peg of the axis. The entire skull, pivoted on this combination, is thus enabled to turn sideways.



bone." The Romans translated the Greek name into the literal Latin equivalent—that is, os sacrum.

The sacrum is a triangularly shaped bone, which tapers sharply downward. It gives solidity to the lower end of the spine. Along its upper sides, the sacrum is attached to the hip bones. Through the place of attachment—the *sacroiliac joints*—the weight of the body is transmitted to the legs. These joints are relieved of strain only when we are lying down; consequently it is no wonder that they frequently cause trouble.

The lower end of the sacrum carries a series of small bones called the *coccyx*, representing the vestiges of a tail. The coccyx serves no useful function. It may be broken if one sits down viotlently on hard ground; such an accident may be extremely painful and may call for the removal of the coccyx.

STERNUM

The breastbone, or sternum, looks like a dagger pointing downward. To the "handle" of the dagger is hinged the narrower "blade," consisting of four fused segments. The tip, or point, of the dagger consists of cartilage in youth, but becomes bony in middle life.

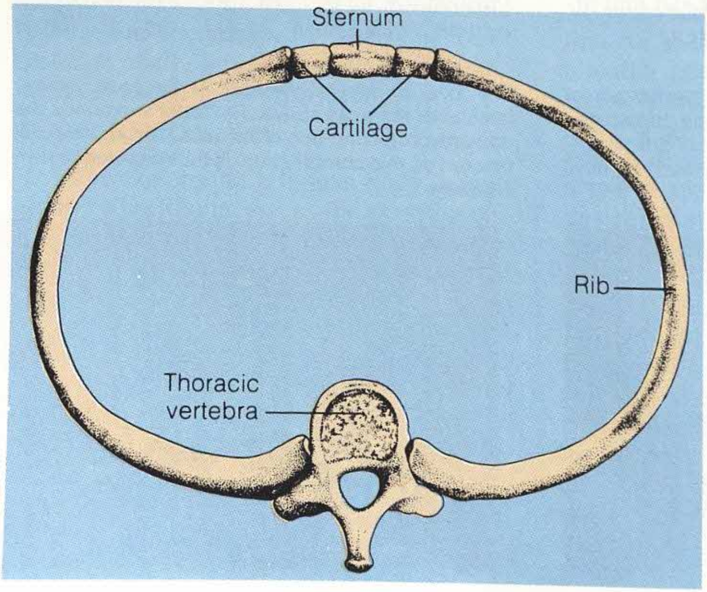
The cartilages of the first seven ribs are attached to the sides of the sternum. The two clavicles, or collarbones, are joined to its upper part. The wide "handle" of the sternum protects the great blood vessels diverging from the heart. The "blade" and the adjacent rib cartilages guard the heart itself.

RIBS

The ribs consist of twelve paired bows of bone. One pair is attached to each of the twelve thoracic vertebrae. They swing toward the front of the body. To their ends are attached elastic bars of cartilage known as *rib cartilages*.

The first seven pairs of rib cartilages reach the breastbone, at the front of the chest, and the ribs to which they are attached are known as the *true ribs*. The next five pairs of ribs are called the *false ribs*. The cartilages of the first three pairs of false ribs are attached in each case to the ribs immediately above. In the case of the last two pair—also known as *floating ribs*—the cartilages have been reduced to short, pointed tips that are not attached to anything. The floating ribs extend only halfway around the body.

When we take a breath, the ribs are lifted upward and swing out, and the lower part of the breastbone swings forward too. All this increases the girth of the chest. At the same time the *diaphragm*, the domed



A horizontal section through the chest region. In the true ribs, as seen at left, cartilage connects the rib to the sternum, or breastbone, in the front of the body. In the back the rib is attached to a thoracic vertebra.

muscular partition separating the thorax above from the abdomen below, contracts. This lessens its curvature and lengthens the up-and-down dimension of the chest. The increase in chest size allows air to be drawn into the lungs through the trachea, or windpipe.

Expiration (breathing out) takes place automatically and mechanically—unless of course we consciously try to hold our breath. Normally the muscles that move the ribs relax, and the elastic recoil of the rib cartilages brings the ribs back to their former position. At the same time the diaphragm also relaxes and again arches upward. All this diminishes the chest size. The lungs contract, air is forced out through the windpipe, and we have completed another of our breathing cycles.

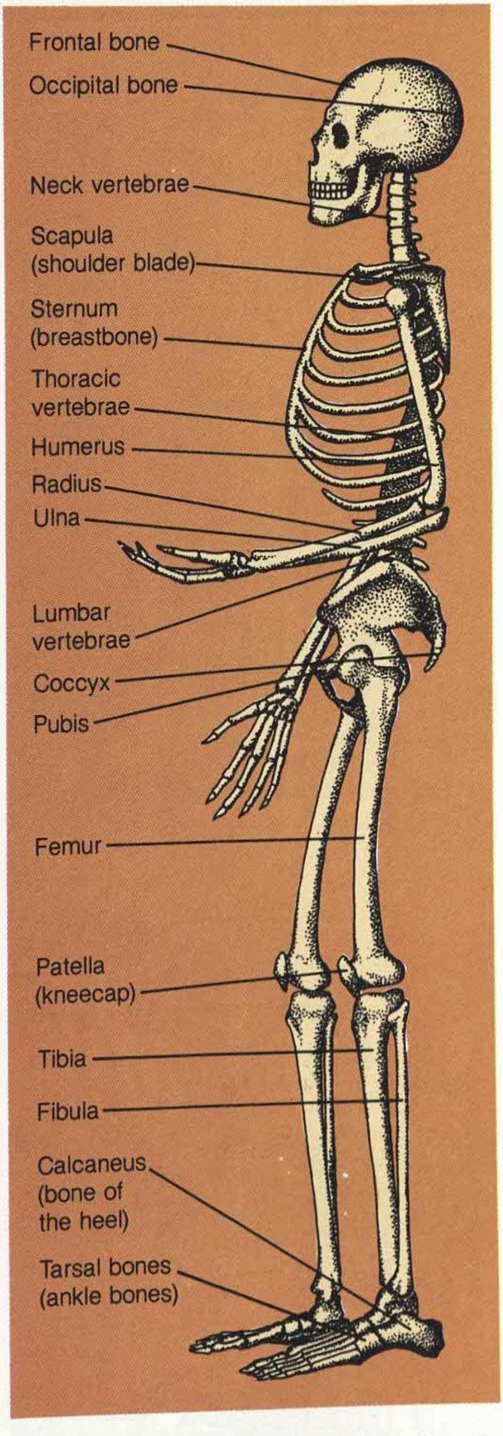
Not only do the ribs play an important part in breathing but they also shield the heart and lungs. Some of the abdominal organs, including the stomach, liver, and kidneys, are protected by the lower ribs.

THE APPENDICULAR SKELETON

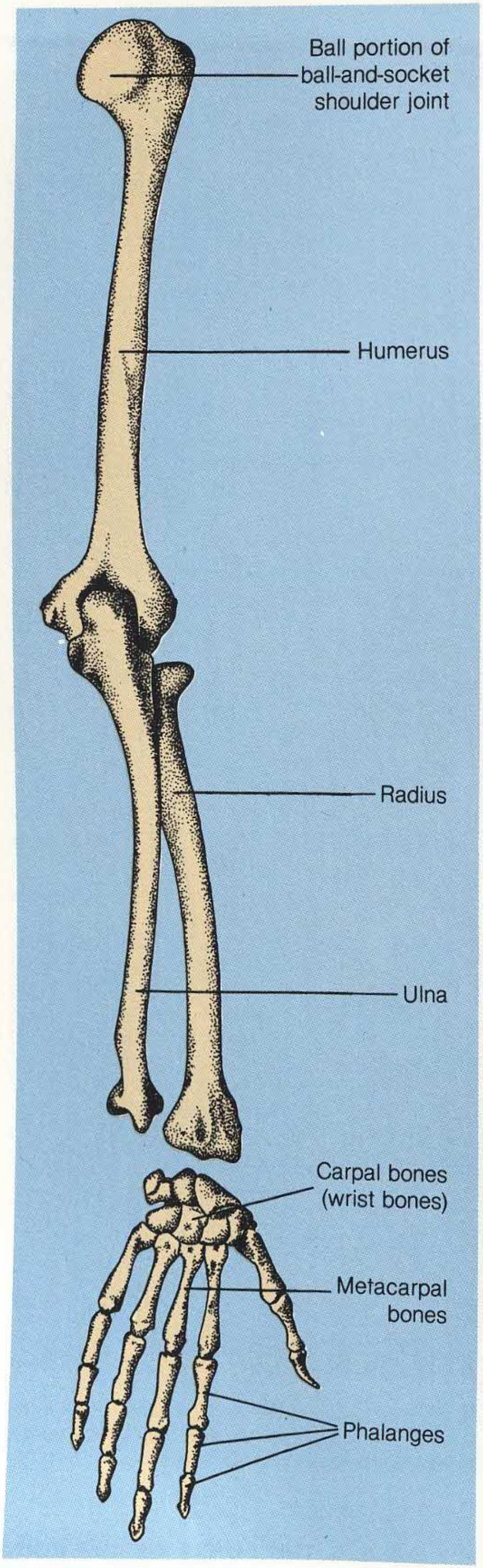
The appendicular skeleton is made up of the shoulder girdle and the pelvic girdle. The shoulder girdle includes the collar bone, the shoulder blade, and the upper limb, or arm, bones. The pelvic girdle includes the bones of the pelvis and the lower limb, or leg, bones.

CLAVICLE

The clavicle, or collarbone, is a slightly curved horizontal structure. It gets its name from its resemblance to a type of key common in ancient Rome. (*Clavis* is the Latin word for key.) At its inner end the clavicle is united to the breastbone. At its outer end, about two centimeters from the point of the shoulder, it is attached to the shoulder blade. The clavicle is really a horizontal strut, forcing the shoulder joint to keep its distance from the breastbone no matter how varied its movements. The swing of the clavicles can be felt when the shoulders are shrugged, depressed, brought forward, or thrown backward. When the collarbone breaks, the shoulder collapses inward, and these movements are no longer possible.



The major bones of the body as viewed from the side. In this view, you can see the normal curvatures of the body.


Ball portion of ball-and-socket shoulder joint
Humerus
Radius
Ulna
Carpal bones (wrist bones)
Metacarpal bones
Phalanges

The bones of the human arm, including the hand. Compare this arrangement with that of the leg.

SCAPULA

The scapula, or shoulder blade, is a thin, triangular bone suspended from the outer end of the clavicle. It is buried in powerful, heavy muscles and moves over a considerable distance as it slides over the upper and back part of the chest. At the armpit the outside border of the scapula forms the socket portion of the flexible *ball-and-socket joint* between the shoulder blade and upper arm. Because of this joint, the upper arm can move in all directions. Ordinarily bones can move in only two directions at the joints—that is, forward and backward.

Running across the back of the shoulder blade is a projecting ledge of bone: the spine of the scapula. As it passes toward the shoulder joint, it becomes more and more prominent until it finally expands into a large bony hood called the *acromion process,* that protects the vital ball-and-socket joint of the shoulder. The hood ends in a projection. The clavicle is attached to this.

Another strong piece of bone projects forward from the upper border of the shoulder blade just beside the shoulder joint. It is about the size and shape of a bent finger or crow's beak, pointing downward. It is called the *coracoid process,* and from its tip muscles stream down the front of the arm. The clavicle is firmly bound to the coracoid process by a strong ligament.

ARM BONES

Humerus. In the upper arm there is but one bone, the humerus. Its knoblike upper end forms the ball portion of the ball-and-socket shoulder joint. The four muscles that immediately surround the shoulder joint are attached to the outer part of the knob. Since the scapula and the humerus fit rather poorly, it is these muscles that hold the bones in close contact.

The upper part of the humerus shaft is at first cylindrical. As it approaches the elbow it flattens out and expands sideways. There are two joint surfaces, side by side, at the expanded end of the humerus. The inner one resembles a spool, pulley, or hourglass laid on its side. It is known as the *trochlea*, the Greek word for pulley. The inner bone of the forearm, the *ulna*, hooks on to the trochlea from behind.

Radius and ulna. Because the ulna is primarily concerned with bending and straightening the elbow, it is thick and massive at the elbow and tapers to a disklike head at the wrist. The *radius* carries the hand at the wrist and so is thick and heavy there. It narrows at the elbow to the same kind of disklike head that the ulna displays at the wrist.

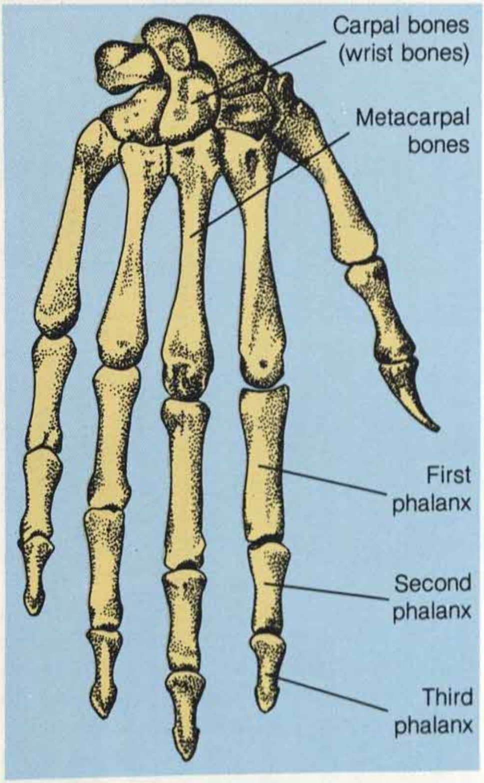
The upper end of the ulna looks like a monkey wrench whose jaws grasp the lower end of the humerus. The part of the ulna that bends around the trochlea of the humerus is called the *funny bone*. It is the projection we feel when we run a finger along the elbow. The nerve running to the ulna passes close by it and when we strike the funny bone, this nerve tingles.

When the palm is directed forward and the thumb is pointing away from the body, the radius and ulna lie side by side. As we turn the palm so that the thumb is directed toward the body, the radius turns. Its shaft and lower end roll across the ulna. Thus, with the thumbs pointing toward the body, the forearm bones are crossed.

HAND BONES

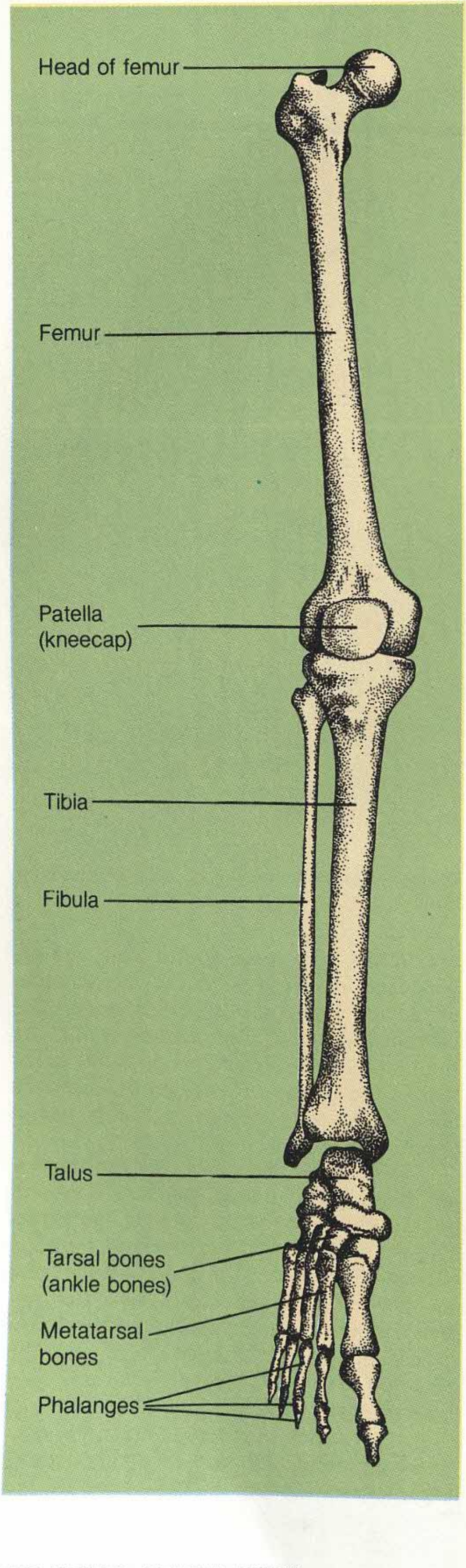
Carpals. The wrists consist of eight little bones, called carpals, that together make up the *carpus* (Greek for wrist). These bones are arranged in two rows of four bones each, the lower row supporting the bases of the bones that lie in the palm. The varied movements of the carpal bones contribute a good deal to the flexibility of the wrist.

Metacarpals. The bones in the palm of the hand, called *metacarpals*, are arrayed beside one another like the sticks of a fan. Their square bases are in contact with one another and can move but little. Their rounded heads form the *knuckles*, and they are not in contact. Between them run little tendons which reach the free fingers. Because the metacarpals diverge from one another as they come off the wrist, the fingers tend to spread when they are straightened and to come together when one clenches the fist. The metacarpal of the thumb moves freely and is opposable to the rest of the fingers. This feature causes the hand of man to be a remarkably useful organ.



The bones of the human hand, as viewed from the front.

Phalanges. The phalanges are the finger bones. The thumb has two bones in line; each of the other fingers has three. These bones are flat in front and rounded behind. The bases of the first phalanges rest on the rounded knuckles. Here the fingers can be bent and straightened and also spread apart and brought together. The other joints serve as hinges, permitting only bending and straightening. The terminal phalanges – those farthest from the knuckles – have triangular tips that support the fingernails.



The bones of the human leg, including the foot. The structures correspond to those of the arm.

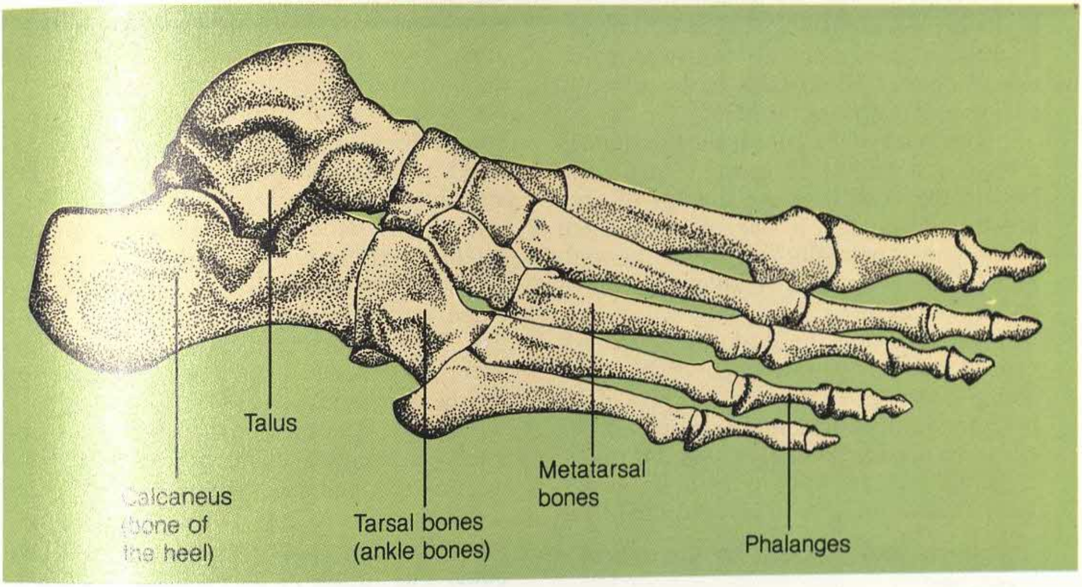
HIP BONES

The hip, or flank, bone is so irregular in shape that it deserves its scientific name of *innominate bone* (from the Latin *os innominatum:* "bone without a name"). It consists of two symmetrical parts attached above to the sacrum and uniting below at the crotch. Three sets of bones make up the hip bone: the *ilia*, the *ischia*, and the *pubes* (plural, respectively, of ilium, ischium, and pubis).

Ilium. The two ilia are the topmost bones. Each ilium is a large curved structure. It is attached to the sacrum at the sacroiliac joint, which we have already described. The ilium is the bone that we feel when we place the hand on the hip. The large surface of the two ilia gives protection to the lower abdominal organs.

Each ilium narrows as it descends. At its lower end it is hollowed out into a cuplike structure about five centimeters in diameter. This is the circular socket known as the *acetabulum* ("vinegar cup" in Latin), because of its fancied resemblance to a small Roman cup that held vinegar or a sauce. The acetabulum receives the rounded head of the thigh bone, or femur, and with it forms the hip joint, the most secure ball-and-socket joint in the body. There are, of course, two acetabula, one on each side of the body. The ilia are very strong. They transmit the weight of the body to the legs.

Ischium and pubis. A stout column of bone, called the ischium, runs almost vertically downward from the acetabulum. It is the bone we rest on when we sit up straight. The ischium merges with a bony ring known as the pubis. The three sets of bones of the hip region—the ilia, ischia, and pubes—together with the sacrum form a bony basin, with the bottom knocked out, known as the *pelvis* (latin for basin). Its deep cavity houses the reproductive organs as well as the lower parts of the digestive and urinary systems. At birth all infants must pass from the uterus down through the bony circle of the pelvis, which is wider in women than in men.



The bones of the human foot. Note the special structure of the heel bone or calcaneus.

LEG BONES

Patella. The kneecap, or patella ("little pan"), is a small triangular bone lying in front of the lower end of the femur. It is imbedded in the thick tendon that passes over the knee joint from the femur to the lower leg. The kneecap slides down the femur when the leg is bent to protect the widely gaping knee joint.

Femur. The thighbone, or femur, is the longest bone of the body. Its neck, representing the upper eight centimeters of its cylindrical shaft, is bent inward and is surmounted with a bony ball, or head, which fits snugly in the acetabulum. As the femur approaches the knee it expands sideways into a pair of prominences known as *condyles*. The condyles rest and move on the flat top of the tibia, the stout inner bone of the leg.

Tibia and fibula. There are two bones in the leg, just as there are two in the forearm. The inner one, called the *tibia,* is very stout and strong. It alone receives and transmits weight. The outer one, the *fibula,* is thin and delicate. At the ankle joint the fibula rests in a hollow on the side of the tibia and is bound very firmly to it. Beyond this place the fibula projects downward as a *flange*—the bump we feel on the outside of our ankles—where it forms an important side support for the ankle joint. The fibula takes no part in the knee joint, which is formed by the articulation, or meeting, of the femur and the tibia.

The tibia is flat on top and supports the condyles of the femur. It is firmly held to the condyles by strong ligaments. As the tibia descends, its shaft tapers. Below, it expands a little again to take part in the ankle joint. It ends in a flange of bone, forming the inner ankle. The flanges of the fibula and tibia hold the talus—the topmost bone of the foot—as in a vise. At the ankle joint the foot can be bent up or down but there is normally no side play. A severe twist of the ankle may break either flange, but usually that of the fibula.

FOOT BONES

The *talus,* the uppermost bone of the foot, rests below on the heel bone, or *calcaneus,* which takes most of the strain when we stand or walk. The talus does not rest squarely on the calcaneus. The front part forms a rounded head that projects beyond the calcaneus toward the inner side of the foot. The talus, calcaneus, and the five small bones in front of them are called the *tarsals*. In front of these again are the *metatarsals* and *phalanges*, comparable to the metacarpals and phalanges of the hand.

The head of the talus is the keystone in a high arch that gives spring to our walk. Should the head lose the support of ligaments and muscles, it sinks down and the foot becomes painfully flat. This is the well-known condition that is known as fallen arches, or flat feet.

The heel and the little toe of the advanced foot receive the weight of the body. The great toe gives the thrust to propel the body forward. If the arch begins to fall, the effort required to give this forward thrust is a painful one. In order to avoid it, the sufferer shuffles along with his feet turned out.

INJURIES AND DISEASES OF THE BONES

Bruises are the commonest of all bone injuries. Who has not bumped his arm or barked his shin? A bruise causes the tearing of blood vessels. As a result blood escapes into the surrounding tissues and there is a swelling. When the blood is absorbed again, the swelling goes down. Unless a bruise has been unusually severe, it has no marked permanent effects.

Far more serious are fractures, or breaks in the bone. The bones of the young are very soft. Hence they often splinter only on the convex side instead of breaking completely. This condition is known as a *greenstick fracture*, because a green twig splinters in much the same way. As one grows older, the bones break more easily. The bones of the aged are particularly brittle; so are those of persons suffering from the rather rare ailment called fragilitas ossium ("fragility of the bones").

There are two general classes of fractures—simple and compound. In a *simple fracture* the skin is not broken. In a *compound fracture* the skin is broken and the injured bone is exposed to the outer air. Compound fractures are always dangerous, because germs may enter the wound.

A fracture is a dramatic thing. In the twinkling of an eye it can transform a perfectly healthy individual into a cripple.

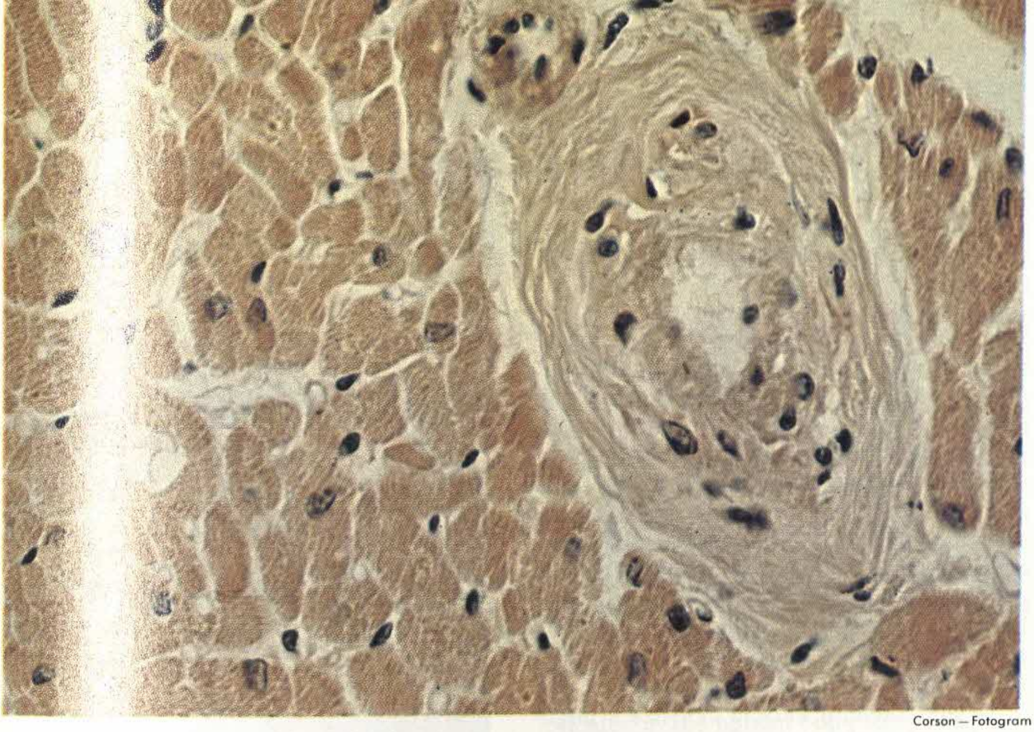
The diseases that attack the bones perform their work more slowly, yet they are often more deadly than fractures. One of the best-known children's diseases is *rickets*, which brings about deformity of the bones. Rickets is due to a faulty diet in which calcium, phophorus, and vitamin D are not adequately represented. As a result of this deficiency, the bones do not solidify properly. The child becomes knock-kneed or bowlegged, his spine becomes curved, and there are other deformities. The treatment consists of supplying an adequate diet and exposing the patient to sunshine or ultraviolet rays.

In some diseases the bones become inflamed. We find this condition in *osteomyelitis* ("bone-marrow inflammation"). It results when certain bacteria of the staphylococcus group infect the inner part of the bone. Pus forms in the stricken area and there is pain and fever. The pressure of the pus may destroy the blood vessels in the marrow. This may cause the death of the bone. If the pus is not drained in time, general blood poisoning may result.

Tuberculosis of the bone is a chronic, or persistent, kind of inflammation, produced by the same bacillus that brings on tuberculosis of the lungs. The bacillus attacks the ends of the long bones or the vertebrae. It causes ulcers to form and makes the bone rot away. Its effects are slow but become increasingly severe in time.

Both osteomyelitis and tuberculosis of the bone are curable if treatment is started at an early stage. Drainage of the affected areas and rest are important in any cure.

Sometimes the bones are attacked by *tumors*, which really consist of new bone growths. Malignant tumors are particularly serious. They gradually destroy the bone itself and they may also appear in other parts of the body. A possible cure is removal of the bone. This measure is not always effective. Radioisotope therapy is sometimes helpful. In some cases, cancer originating in the breast, kidney, or other regions of the body may be spread to the bones by way of the blood or lymph. Gradually healthy bone is replaced by cancer tissue, and in time any ordinary exertion may bring about a fracture.



Corson – Fotogram

People often do not think of the heart as a muscle, but it is – the most important muscle in the body. Above is a microscopic section of heart muscle, showing light and dark sections and, in the light oval, a duct.

THE MUSCULAR SYSTEM

When a small boy offers to show you his muscle, the chances are that he will proudly display his *biceps* – the upper arm muscle that you can feel hardening, swelling, and shortening when you bend your elbow. But the biceps, after all, is only one of more than 600 different muscles in the human body.

WHAT MUSCLES ARE

The muscles are essential to life because, by alternately contracting and relaxing, they account for all body motion. Some muscles move the limbs; others open and close the eyelids; and still others help us digest our food. The heart is a mass of muscle which keeps working tirelessly day after day.

Muscles vary greatly in size and shape. They range from the great *latissimus dorsi,* which is the broadest muscle of the back, to a threadlike ear muscle that is only about five millimeters long.

Muscle corresponds to the red animal meat that we see in the butcher shop. To get a rough idea of the structure of muscle, let us examine, say, a leg of lamb. This cut of meat usually contains several muscles separated from each other by a tough whitish sheath called *connective tissue.* This is sometimes loose and thin, sometimes dense and thick. Some connective tissue forms *tendons,* or sinews – cords or straps that attach the ends of muscles to the bones. Parts of tendons are often seen in meat. No matter how long the meat is boiled, these tendons defy vigorous chewing – that is, they do not soften.

TYPES OF MUSCLE

Human muscle shows connective tissue like that which we have just described. A microscope will reveal many other interesting details. We discover, for one thing, that the masses of muscle separated by connective tissue are really bundles of very firm threads, or *fibers.* In length, muscle fibers range from about one millimeter to more than 30 centimeters. Some of them run from one end of a muscle to the other.

Some are joined by connective tissue so as to form long chains.

There are three kinds of muscular tissue in the human body: *skeletal, smooth,* and *cardiac*.

Skeletal muscle. Skeletal muscles are by far the most numerous of the three basic types. As their name implies, they are generally attached to the skeleton. Skeletal muscles are also known as *striated,* or *striped,* muscles because they are made up of light and dark cross-striped bands. Still another name is *voluntary muscle:* skeletal muscles can be controlled by the mind. For example, you can move your arm by means of skeletal muscles whenever you wish, but did you ever try to control the smooth muscle of your stomach as it churns away in the process of digestion?

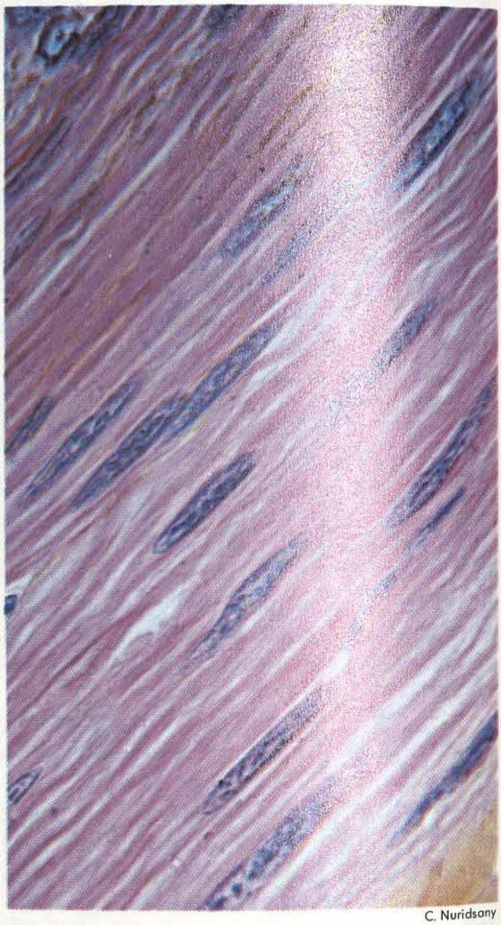
Each skeletal muscle cell has a large number of nuclei – sometimes as many as several hundred. These nuclei lie in the outer part of the cell. In this respect skeletal muscle cells differ from most other muscle cells, in which a single nucleus is located more or less in the center of the cell.

Smooth muscle. Smooth muscles do not show any cross stripes. Since we do not have any control over their movements, they are also called *involuntary muscles.* They are found, among other places, in the walls of the stomach and the intestines, in the bladder, in the blood vessels, around the pupils of the eyes, and attached to the roots of the hair. These smooth muscles contract more slowly than skeletal muscles.

Cardiac muscle. Cardiac muscle, or heart muscle, resembles smooth muscle in that its activity is not controlled by the mind. It also has a certain similarity to skeletal muscle, since its fibers have a cross-striped pattern.

SKELETAL MUSCLE CONTRACTION

What happens inside a skeletal muscle fiber when it contracts? The ordinary microscope does not help much in this case, and so we call on the biochemist to supply us with information. Biochemical analysis shows that the striped part of the muscle is made up of two types of proteins – *actin* and *myosin.* Researchers have learned much about the arrangement of protein molecules. In the light of this knowledge, we can picture the dark bands of a muscle fiber as made up of rodlike molecules of myosin. These rods lie side by side lengthwise in the fiber. The light bands consist of bent or curved molecules of actin.

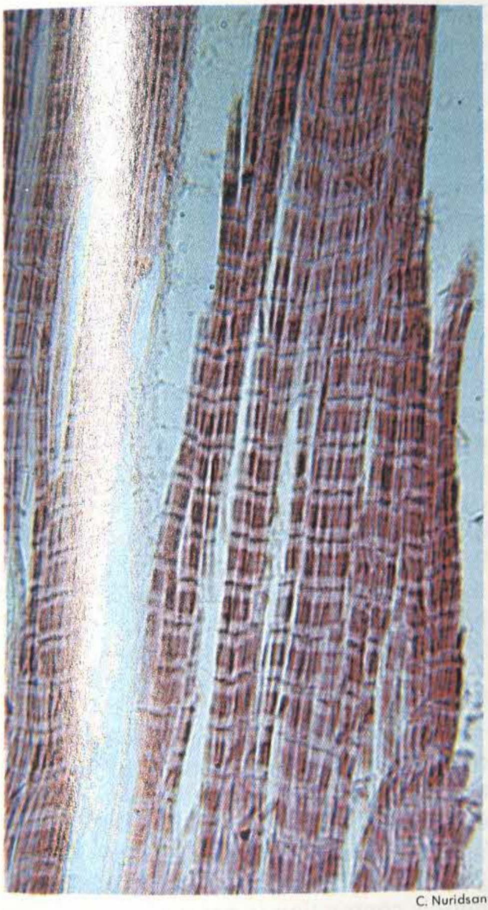


C. Nuridsany

Microscopic section of smooth muscle. Smooth muscle lines most internal organs. It makes up about 3 per cent of the body weight.

During a muscle contraction the straight rods slide past one another, and the whole fiber is shortened.

The total effect of contraction is remarkable because, although muscle is soft, it develops great force. If all the fibers within one square centimeter cross section were to contract at the same time, they would raise nearly 10 kilograms. The muscles



C. Nuridsany

Microscopic section of skeletal muscle. Alternating light and dark bands are clearly visible and distinguish it from smooth muscle.

used in chewing could lift a man of average weight.

ENERGY FOR MUSCLE ACTION

Muscular activity requires abundant energy. To produce this energy the body consumes various energy-giving foods. Among the most important of these are sugars and starches. During digestion and assimilation, sugar and starch are changed into *glycogen*. Most glycogen is stored in the liver and is given out as needed. Some is found in the muscles and other tissues.

Fat is another body fuel. We probably draw upon it even during light muscular activity. We certainly use it when our stores of glycogen are greatly reduced during long, exhausting exercises or when we go on a diet containing very little starch or sugar.

Fuels such as coal, wood, and gasoline contain carbon. So do many of the foods that we eat. When fuels are burned, the carbon they contain combines with the oxygen of the air to form carbon dioxide. During this process heat is produced and is used in various ways. In a locomotive, for example, it causes water to be transformed into steam, and this steam pushes pistons to and fro in cylinders. The carbon of foods combines with the oxygen carried by the blood. In this process, too, carbon dioxide is formed and heat is produced. The carbon dioxide is carried by the blood to the lungs and there it is breathed out.

Fuel consumption is much more complicated in the human body than in a locomotive or automobile. The body does not burn glycogen directly but breaks it down into lactic acid. Then some of the lactic acid (about one-fifth) is burned – that is, it combines with oxygen. The remaining lactic acid is reconverted into glycogen.

When we want to contract a muscle, we must have energy ready for immediate use. It would take too long to wait for the breakdown of glycogen and the burning of lactic acid. Another mechanism provides energy for muscle activity more quickly. This mechanism involves the breakdown of phosphorus compounds present in muscle tissue.

One of the compounds – adenosinetriphosphate, or ATP – breaks down, providing the energy necessary for muscle contraction. A second compound, called phosphocreatine, also breaks down and in so doing provides the energy to build up ATP again so that it will be ready for the next contraction.

Glycogen then decomposes into lactic acid, which provides the energy for the buildup of phosphocreatine. Any excess lactic acid is carried by the lymphatic system, to the liver, where it is reconverted into glycogen, the primary energy storage molecule.

This may seem to be a roundabout way to get results, but it really is most efficient.

STRUCTURE OF A MUSCLE FIBER

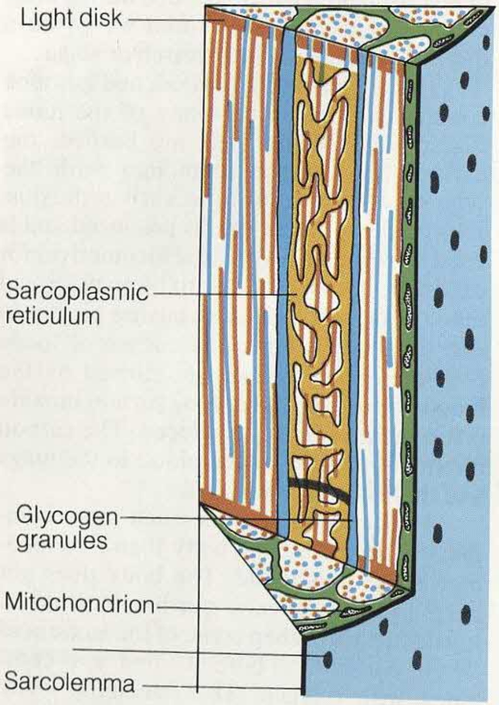


Diagram of muscle structure. The cytoplasm of a muscle cell – sarcoplasma – is shown as are other cell parts and glycogen molecules.

If muscles contracted only as a result of the energy supplied by burning, we could not engage in sudden spurts of activity. For example, a sprinter may require only ten seconds or less to run 100 meters. He would not have time, in that short period, to inhale all the oxygen required for combustion within the muscles.

For a time, therefore, the oxygen supply will lag behind the demand. The go-betweens that we have mentioned – glycogen, lactic acid, and the two phosphorus compounds – will keep the muscles functioning for a considerable period. After the race the sprinter can gulp in oxygen at his leisure, burn up the accumulated lactic acid, and rebuild his supply of glycogen.

MUSCLE FATIGUE

If too much lactic acid accumulates within a muscle, it becomes tired and finally stops contracting. If muscles are to act effectively, lactic acid must be broken down into carbon dioxide and water or built up into glycogen. The waste products resulting from the activity of muscle cells also produce fatigue. If they become too abundant in the blood, they may even affect organs which have not been active. Rest after exercise is good, because it allows fatigue-producers to be destroyed or passed out of the body.

We have pointed out that muscles must be well supplied with glycogen and oxygen and that they must get rid of the waste products of combustion by way of the circulatory system. If all the arteries leading to a muscle and the veins leading away from it were to be shut off, the results would be serious. Within a short time, the muscle would suffer great damage. It would die if the condition lasted for more than a few hours. Oxygen would not be brought to the muscle, and lactic acid would not be burned. The waste products accumulating in the muscles would not be carried away.

AN EFFICIENT SYSTEM

Considered as a machine – something that uses energy to do work – the muscles compare favorably with man-made machines. They are more efficient in one important respect, for while machines waste a good deal of heat, the heat produced by muscle contraction is not wasted. It serves to warm the blood, which in turn warms other tissues. This is a most necessary function, because unless body temperature is maintained, all cell activities slow down, and finally death results. When we shiver in cold weather, we are really calling upon our muscles to produce extra heat in order to maintain body temperature.

CONTROL OF MUSCLE ACTIVITY

How do we start our muscles working? A number of body structures are involved – not only the muscles but also the brain, the spinal cord, and the nerves. The nerves connect the brain or spinal cord with the skin, muscles, and other tissues. They contain fine long threads, called *nerve fibers,* which serve the same purpose as telephone lines. If, for example, you wish to bend your elbow, you send messages from your brain down the spinal cord and out along the nerve to the biceps muscle in the upper arm. Beyond the first place of contact between a nerve and its muscle, each nerve fiber divides into many branches and each branch goes to a muscle fiber. A message along one nerve fiber may cause as many as 100 muscle fibers or even more to contract.

When messages are sent by way of nerve fibers to a muscle, only a part of the muscle fibers are called on to contract. They always contract completely. Therefore, when more force is required for a given task, messages must be sent along more nerve fibers. Moreover, if a muscle fiber receives only one message, it contracts for only a fraction of a second. Therefore, in the case of an ordinary muscle movement, we send messages rapidly one after another in order to catch the muscle fibers before they relax.

If necessary, another muscle may be called on to help perform a given task. This is because at almost every joint there are several muscles that help bring about the same movement. Muscles that work together to produce the same movement are *synergistic*. In certain other cases, muscles that normally oppose a given motion may be called on either to relax or to offer greater resistance. These muscles are *antagonistic*.

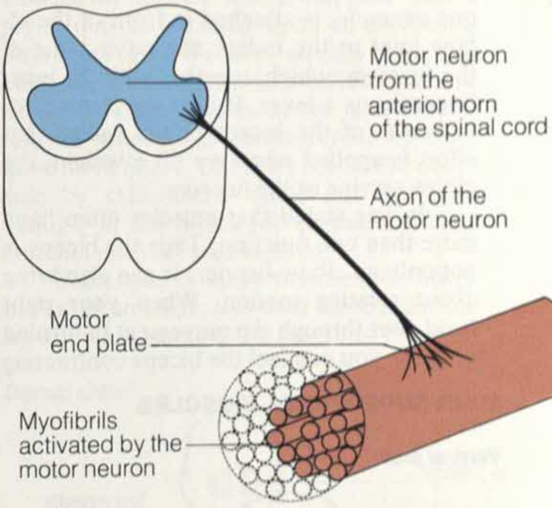
MUSCLE MOTION

Muscles can perform a variety of movements, although not all muscles are capable of all movements. At the elbow, for instance, there are bending muscles, such as the biceps, and straightening muscles, such as the triceps at the back of the arm. *Flexor* muscles bring adjacent body parts closer together; *extensors* move them apart. *Abductors* move a part, such as a limb, away from the rest of the body; *adductors* move it back.

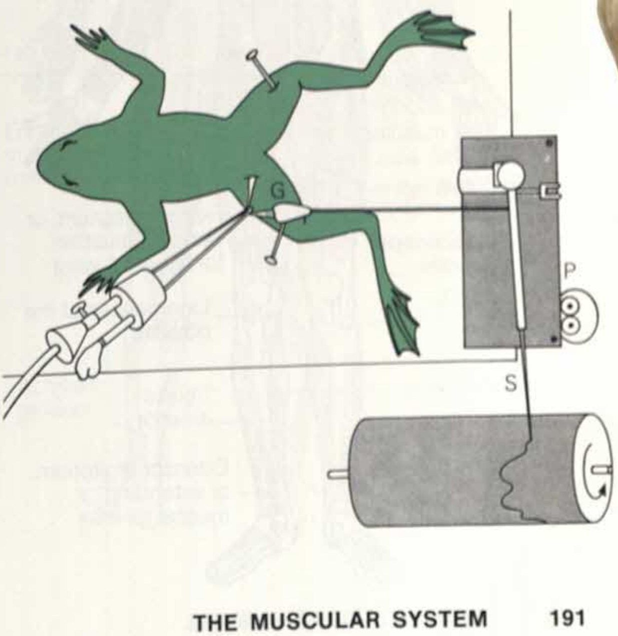
There are also muscles for side-to-side movements, such as those of the wrist. *Pronator* muscles can turn a part, such as the hand, face up; *suppinators* turn it face down. There are also muscles for *rotation*, as at the shoulder and the hip joints.

In all these cases the bones act as lev-

DIAGRAM SHOWING A MOTOR NEURON


Motor neuron from the anterior horn of the spinal cord
Axon of the motor neuron
Motor end plate
Myofibrils activated by the motor neuron

Muscle contraction is controlled by the nervous system. The diagram above shows how a nerve fiber extends from the spinal cord (blue) to a muscle fiber (pink). The nerve transmits the message for the muscle to contract. An understanding of such nerve-muscle action has been gained through much experimentation. In one type of experiment, depicted below, the effect of sciatic nerve stimulation on the gastrocnemius muscle of a frog was studied. The rate and extent of the muscle's contraction was recorded on a drum.

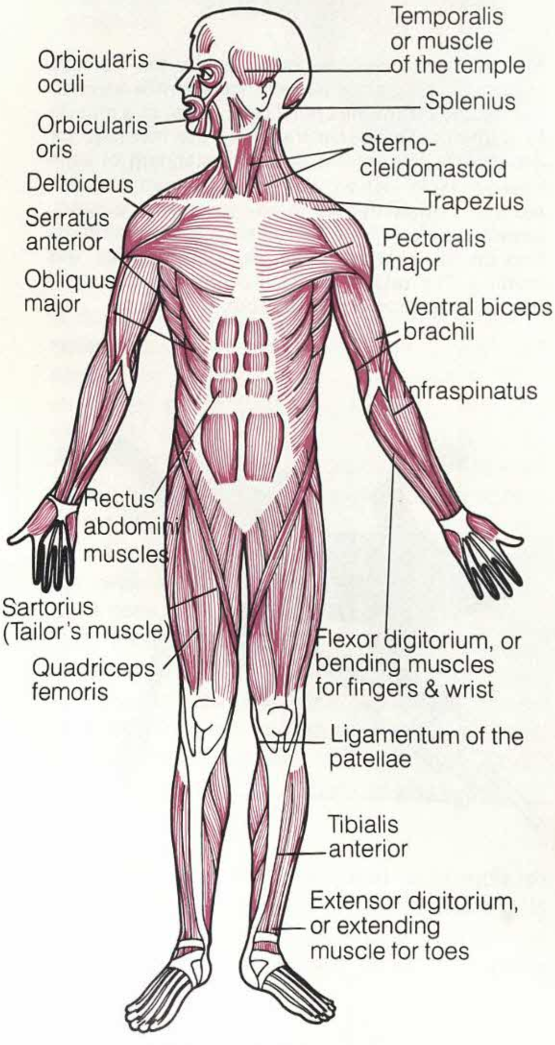


ers, and the muscles exert the forces that cause motion. The biceps muscle, to give one example, is attached in front of the elbow joint to the radius, the outer bone of the forearm, which, together with the inner bone, forms a lever. It is at the place of attachment of the biceps to the radius that effort is applied when we lift a weight, the elbow serving as the fulcrum.

It was stated that muscles often have more than one function. Thus the biceps is not only an elbow-bender. It can also bring about rotating motion. When your right hand goes through the movement of turning a screw, you can feel the biceps contracting to rotate the outer bone of the forearm, which carries the hand around with it. As this takes place, the triceps at the back of the arm contracts so as to prevent the biceps from bending the elbow.

MAIN SUPERFICIAL MUSCLES

Ventral side



MUSCLES ACT IN GROUPS

We can study the action of individual muscles, but it is important to remember that muscles act not singly but in groups. We saw that both the biceps and the triceps come into play when we turn a screw. A simple experiment will reveal another case of cooperation between muscles. Move your right arm out from the body and then bring it down slowly while feeling the *deltoid muscle* with your left hand. The deltoid muscle, shaped like a reversed Greek letter Δ, or *delta,* covers the shoulders. Gravity keeps pulling your arm down. The deltoid muscle gradually relaxes. Repeat the movement, but this time have someone resist the downward sweep of your arm by holding up your elbow. Now other muscles, such as the pectoralis major (greater breast muscle), come into play. As they meet continued resistance, the deltoid becomes more and more relaxed.

This experiment reveals that gravity often serves to lessen the wear and tear on muscles. It also shows that proper muscle relaxation is as important as contraction. Suppose, for example, that a football player or a dancer wants to do a high kick, bending the hip while keeping the knee straight. He must first learn to relax the muscles of the back of the thigh which cross the hip joint and knee.

Even widely separated muscles may play a part in exerting a given force. When we push or pull a heavy load, the abdominal muscles are rigid. Often in such a case we stop breathing, because the muscles of the voice box in the neck have contracted, thus preventing air from passing up or down. The chest and abdomen have become a rigid mass, giving strong support to the arms.

The abdominal, or body-wall, muscles oppose the action of the *diaphragm,* the dome-shaped muscular sheet between the chest and the abdomen. When we breathe in, the diaphragm contracts, deepening the chest cavity, and air rushes into the lungs. In doing so, the diaphragm pushes the abdominal organs downward. The abdominal wall muscles relax somewhat. When we breathe out, the diaphragm relaxes and the muscles of the abdomen contract.

Other opposing muscles are arranged in such a way as to open and close the mouth and the eyelids. Circular muscles, called *sphincters,* cause the mouth to close. It is opened by muscles that run toward it like the spokes of a wheel. For eye-opening there is the forehead muscle, which wrinkles the forehead when we open the eyes widely, and a muscle that lifts the upper lid.

The face muscles around the mouth and the eye are interesting because they are attached to the skin and not to the face bones, although they are skeletal muscles. We use them to express our feelings—anger, joy, sorrow, fear—and so they are called *muscles of expression.* They are developed from the same sheet that produces the platelike muscle attached to the skin of the neck. Certain animals have a big sheet of such muscle over the body. If a horse, for example, is annoyed by flies, it will cause its skin to quiver. Thus it will shake off the insects.

TENDONS

Muscles are often made far more effective by being combined with tendons. As we have already pointed out, tendons are bands of connective tissue attaching the ends of muscles to the bones. They are immensely strong. A tendon only six millimeters in diameter can support the weight of from three to six people.

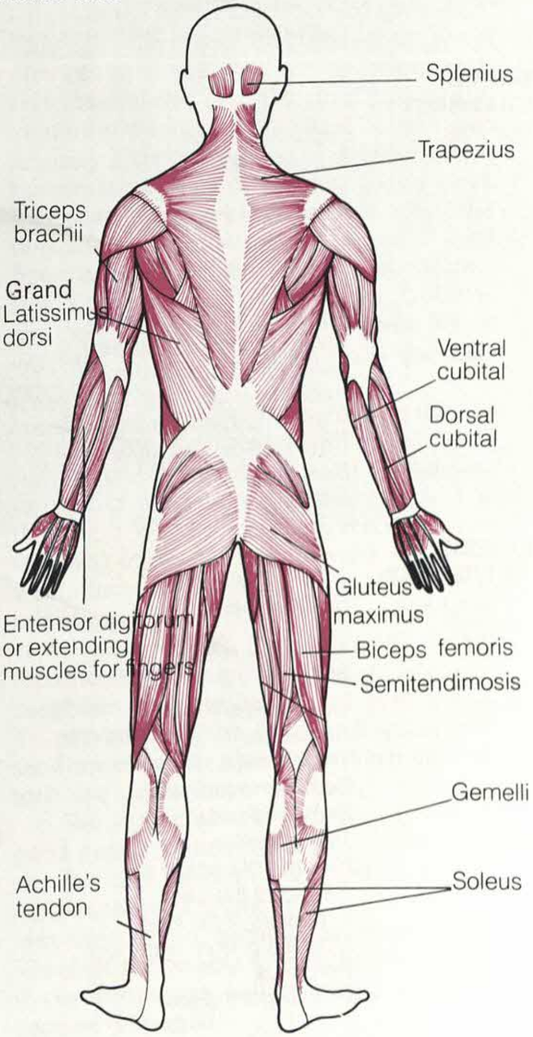
Some tendons are very conspicuous. You can easily feel those which, like tense cords, pass behind the knees. You can also feel the Achilles' tendon, running from the muscle of the calf of the leg down to the projecting heel bone.

People often confuse tendons with *ligaments,* which are also found at joints and are also made up of connective tissue. The difference is that ligaments do not attach muscles to bones but hold one bone to another. That is, they serve to *articulate,* or join, the parts of the skeleton.

Tendons serve to transmit the force exerted by muscle fibers. Suppose that a given muscle is called upon to perform a strenuous task. We have already seen that each muscle fiber exerts a definite amount of force—never more, never less. Therefore, in order to get more force, we must have more fibers. But if we set all the fibers side by side, there would not be room enough on the bones for all the muscular attachments that are involved.

Therefore, in many muscles the fibers are set at an angle, and their force is carried by a tendon running the length of the mus-

Dorsal side



REGION	MUSCLES	FUNCTIONS
HEAD AND NECK	Skin muscles of the face	Facial expression
	Temporal	Chewing
	Masseter	
	Muscles of the nape of the neck	Extension of the head
	Sterno-cleido-mastoideus	Rotation and inclination of the head Breathing
TRUNK Thorax	Chest muscles	Extension and lateral flexion of the trunk
	Trapezius	Shoulder movement; inspiration
	Intercostal muscles	Respiratory movements
	Diaphragm	
Abdomen	Large straight muscle	Flexion of the trunk; expiration
	Oblique and transverse muscles	Protection and maintenance of internal organs
Pelvis	Perineal muscles; posoas	Floor of the pelvis; movement of the thighs
	Lumbosacral and buttock muscle masses	Maintenance of upright position
UPPER EXTREMITY Shoulder	Pectoralis major	Movement of the arm; inspiration
	Dorsalis major	Movement of the arm
	Deltoid	
	Muscles of the shoulder region	Rotation of the arm
Arm	Biceps	Movement of the forearm
	Anterior brachial	
	Brachial triceps	Extension of the forearm
	Square pronateur muscle	Rotation of arm
	Round pronateur muscle	
	Long and short supinators	
	Radial muscles of back of forearm	Movements of the hand
	Radial muscles of front of forearm	
	Extensors of the fingers	Movements of the fingers
	Flexors of the fingers	
Hand	Interbone muscles	Thumb and finger movements
LOWER EXTREMITY Buttocks and beginning of thigh	Buttock muscles	Movement of thighs and maintenance of posture
Thigh	Psoas	Movement of the thigh
	Quadriceps	Extension of the leg
	Adductors	Bringing together of thighs
	Thigh biceps	Bending of the leg
	Semimembranosus	
	Semitendinosus	
Leg	Triceps femor	Movement of the foot
	Muscles of back of leg	
	Flexors of the toes	Bending of the toes
	Extensors of the toes	Extension of the toes
	Muscles of front of the leg	Movements of the foot
	Peroneus	
Foot	Muscles of the sole	Toe movements and maintenance of position

cle. This arrangement gives the muscle the appearance of a feather, the tendon being the quill and the fibers the branches. An example of this type of arrangement is the temple muscle. You can feel it when you grit your teeth.

Tendons, then, serve to economize space that would otherwise be occupied by muscle fibers. Here is another example. Our hands and fingers can perform numerous and infinitely varied movements. We can strike a hard blow with the clenched fist, apply light pressure to a glass we are washing, or delicately poise the fingers to thread a needle. For such a variety of movements we need many muscles. There would not be room for all the necessary muscular attachments to the bones of the hands.

The problem has been solved very ingeniously. Many of the muscles involved in moving the hands and fingers start in the upper part of the forearm. You can feel them when you bend and straighten the wrists and fingers. Near the wrist a great number of fibers are attached to a very few tendons. The forearm muscles manipulate the fingers of the hand by means of these intervening tendons.

Tendons also help muscles to withstand sidewise pressure and friction. Where muscles rub against each other or against bone, they develop protective tendon patches. There are always tendons where muscles have to turn corners, as in passing from the leg to the foot. Here the muscles are shielded by the tendons and the tendons in turn are protected against friction by bags of connective tissue, called *tendon sheaths*.

These sheaths contain a fluid that acts as a lubricant as the tendon slides back and forth. When tendons are moved quickly for long periods of time, the sheath becomes hot and sore and may fill with extra fluid. As a result the joint may swell, and any movement will result in great pain. This condition is called *tendinitis*. The treatment in such cases is rest at the earliest possible moment.

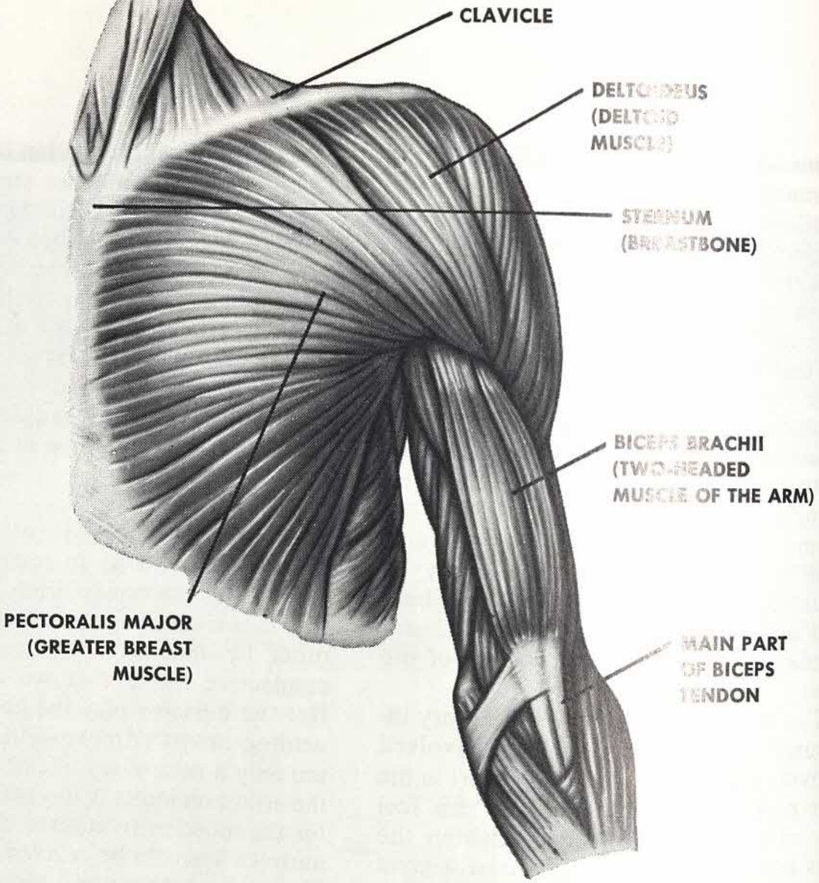
When there is friction on only one surface of a tendon, the connective tissue bags do not surround the tendon but lie between it and the bone or other structure against which the tendon rubs. Simple flattened bags of this kind are called *bursae*. We find them between the kneecap and the skin and in other places where friction occurs. A bursa reacts in the same way as a tendon sheath when there is excessive friction or infection. Its cavity fills with fluid and the walls thicken. This condition is known as *bursitis*, or inflammation of a bursa.

MUSCLE TONE

Muscles are used not only to cause movement but also to restrain movement by holding the bones firmly together. It is true that the bones are attached to one another by means of the bands of tough connective tissue that we call ligaments. But the muscles play the chief part in preventing unwanted movement. The ligaments are only a secondary line of defense, when the strain on joints is too great to too quick for the muscles to control. Even when the muscles seem to be relaxed, some of their fibers are contracting. This partial contraction is called muscle tone or *tonus*. It serves not only to hold the bones in place but to keep the muscles taut and ready for their next time of use.

Muscle tone helps us to maintain an upright position or posture. When we stand still, we can feel the firmness of the muscles in front of the hip joint and in the back of the thigh. We can feel them relaxing when we sway backward and forward. When we walk, the straightening muscle of the backbone keeps us from falling forward. Whether we stand or walk, the earth's pull always tends to make us slump, with bent head and backbone, sagging belly, and bent knees. To prevent this, the brain and spinal cord send messages to muscles to keep up their tone and maintain our posture.

We should always consciously aim at good posture when we stand or walk – or sit, for that matter. Otherwise we shall throw too much strain on some of the muscles involved in maintaining muscle tone. We shall not be able to breathe deeply and, if our bones are still growing, they may become deformed.


CLAVICLE
DELTOIDEUS (DELTOID MUSCLE)
STERNUM (BREASTBONE)
BICEPS BRACHII (TWO-HEADED MUSCLE OF THE ARM)
MAIN PART OF BICEPS TENDON
PECTORALIS MAJOR (GREATER BREAST MUSCLE)

Muscles of the front of the chest and of the upper arm. The clavicle and the sternum are points of attachment for some of these muscles. The interrelationship of the various muscles is clearly seen: you can see how the movement of one muscle will affect other muscles.

MUSCLES CAN CHANGE

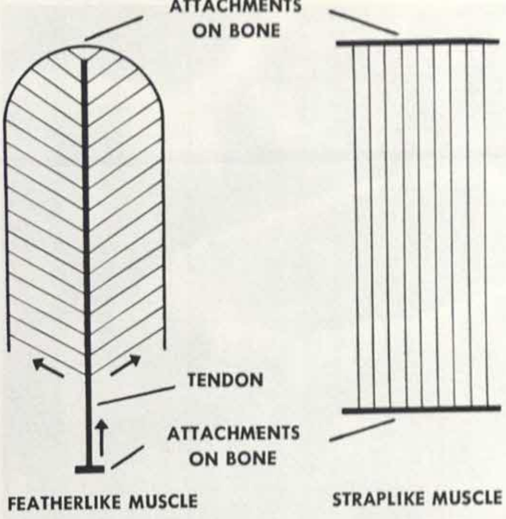
It is commonly known that muscles enlarge when they are exercised. The difference in size is due not to the formation of new fibers but to changes in the girth of the existing ones. A new-born infant's muscles weigh less than one kilogram; an adult's weigh over twenty kilograms because of the enlargement of the fibers. If exercise increases the size of the muscles, disuse causes them to become smaller, as many a bedridden patient can testify.

After injury, muscle fibers do not divide, as do skin cells, in order to repair the wound. The ends of cut fibers grow to replace some of the lost tissue, but most of the repair work is done by connective tissue, which may form a scar. If the entire nerve path to a muscle has been severed by injury or destroyed by disease, the muscle fibers shrink and die. However, in such cases, other muscles can often be trained to perform at least a part of the work that had formerly been accomplished by the now-useless muscle.

Muscle trouble may not always be the result of injury or disease. As a matter of fact, anything that interferes with the proper functioning of the muscle may cause difficulty. For example, muscles control foot bones and help to balance the body. Improperly fitted shoes often cramp these muscles, prolonged standing throws undue strain on them, and foot trouble results. This may affect muscles in other areas of the body, such as the thigh, the back and even the neck and head.

STRAINS AND SPRAINS

Excessive use of a muscle and too much strain upon it may cause stiffness and pain, especially when one tries to use the muscle. This is a rather common ailment



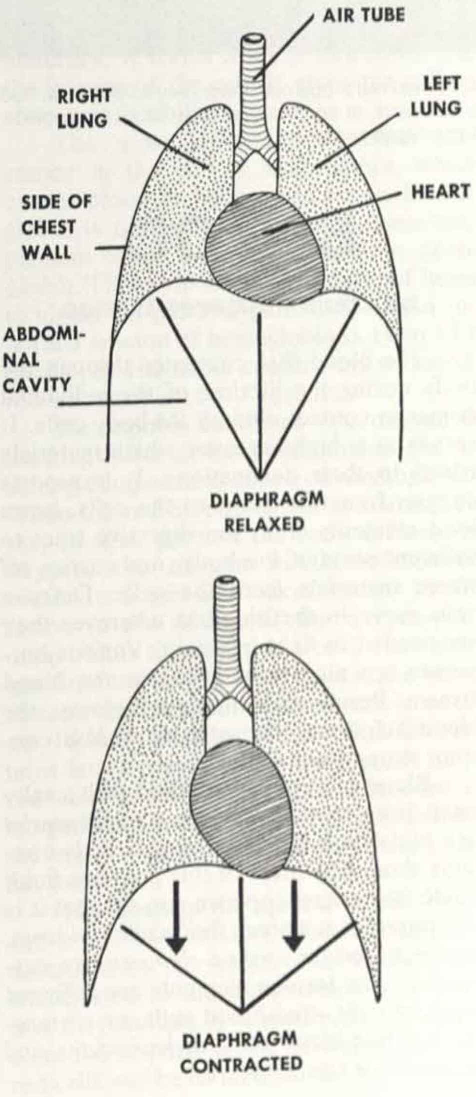
Fibers of skeletal muscle form different patterns. Some, like some large muscles of the back, are featherlike. Others, including some in the abdominal wall, are parallel, or straplike.

among sprinters and baseball players. We do not know just what happens inside a muscle in such cases, since we ordinarily do not remove sections of living muscle for examination under the microscope. However, experiments with animals have shown that when muscle fibers are greatly fatigued, they are more fragile and inelastic than usual. They lose the power to contract.

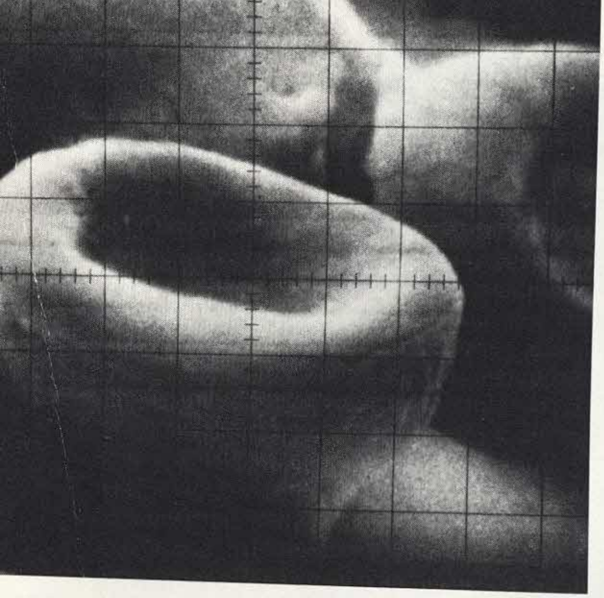
Muscles are sometimes bruised as the result of a blow or fall. In such cases the fibers are injured and numerous small blood vessels are broken. The blood then passes into the tissue, which becomes swollen and painful.

Muscles in the vicinity of joints are particularly likely to suffer the disabling injuries known as *sprains*. These occur when the joints are overstrained or violently wrenched. There is tearing and displacement of tissues inside and outside the joint—the tissues of ligaments, muscles, tendons, tendon sheaths, and bursae. Often there is bleeding into the tissues. Sometimes the connective tissue of muscles becomes inflamed and gives rise to stiff neck and to *lumbago*, which is pain and stiffness of muscles low in the back. Cramps, which occur most often in the foot and leg muscles of the body, are prolonged, painful contractions.

Muscles are often affected by diseases of the nerves, blood vessels, bones, joints, and other tissues. If a muscular disorder does not soon disappear, a doctor should be consulted, for it may be a warning signal of a serious disease.



How we breathe. Middle right: when we exhale, the diaphragm is relaxed and the abdominal muscles (not shown) are contracted. The lungs shrink and gas is forced out of them. Bottom right: when we inhale, the opposite muscle actions occur. The abdominal muscles relax and the diaphragm contracts. The chest and the lungs expand, drawing in a mass of air.



A normal red blood cell, magnified 8,000 times. Red blood cells, or erythrocytes, contain hemoglobin – the oxygen carrier.

BLOOD

by Louis Faugeres Bishop

The blood that circulates through the body during the lifetime of the individual comes in contact with all the body cells. It serves as a highway over which materials travel to their destinations. It transports oxygen from the lungs to the cells, bears food elements from the digestive tract to different parts of the body, and carries off waste materials from the cells. Defense cells move in the blood to wherever they are needed to fight infection. Various hormones are also transported in the blood stream. Besides serving as a highway, the blood helps maintain a more or less constant temperature in the body.

Blood is a red, sticky fluid with a salty taste. It varies in color from a bright scarlet to a bluish red. The adult man's body contains about five liters of this precious fluid. Under the microscope we can see that it is composed of a watery fluid called *plasma,* in which certain *formed elements* are suspended. The formed elements are different types of cells – red blood cells, or *erythrocytes,* white blood cells, or *leukocytes,* and platelets, or *thrombocytes.*

PLASMA

The plasma is the watery part of the blood, making up from 50 to 60 per cent of the total. It is a clear yellow fluid, serving as a vehicle for the transportation of red blood cells, white blood cells, platelets, and various substances necessary for the vital functioning of the body cells. Plasma also acts in blood clotting, and in the defense of the body against disease. After clotting occurs, a straw-colored fluid called *serum* is left. This portion of the blood retains its liquid form indefinitely.

About 90 per cent of plasma is water, in which a great variety of substances are held in suspension or in solution. These include proteins, such as fibrinogen, albumin, and the globulins, and also sugar, fat, and inorganic salts derived from food or from the storage depots of the body. Plasma contains urea, uric acid, creatine, and other products of the breakdown of proteins. There are enzymes, such as adrenal hormones, thyroxine, and insulin, derived from the glands of internal secretion. There are also various gases: oxygen and nitrogen, diffused into the blood from the lungs; and carbon dioxide, diffused into the blood from the tissues.

Proteins. The proteins in the plasma serve several vital functions. For one thing, the cells of the body are made up mostly of proteins. Proteins attract water. If proteins were present only in the cells and not in the plasma, the cells would draw the liquid into themselves until they would be swollen. The proteins in the plasma serve to balance the pulling effect exerted by the proteins in the cells. Serum *albumin* is the plasma protein most concerned with this function.

Among the other proteins contained in the plasma are various globulins. *Gamma globulins* are antibodies that serve to immunize the body against disease. They have been used to give passive immunity to such diseases as measles, infective jaundice, and polio. The globulin *prothrombin,* as we shall see, plays a vital part in the blood-clotting mechanism. *Fibrinogen* is another protein contained in the plasma. It too is involved in clotting.

The various proteins in the plasma can be separated – a development in which the researches of Edwin Cohn and his associates at the Harvard Medical School played an important part. The separation of these proteins is called *fractionation*. Each protein obtained in this way is called a *blood-plasma fraction*.

Salts. The salts in the plasma are useful in various ways. Sodium chloride (common salt) helps proteins dissolve – a vital function, since proteins must be in solution before they can serve their purpose. Other salts in the plasma are known as *buffers*. They serve to maintain the same degree of alkalinity in the blood regardless of whether acids or bases are added.

RED BLOOD CELLS

The erythrocytes, or red blood cells, are the most numerous of the formed elements. Their function is to carry oxygen to the cells throughout the body and to return carbon dioxide to the lungs. There are normally about 5,000,000 in each cubic millimeter of blood in men and about 4,500,000 in women.

Each red blood cell is about 7/10,000 of a centimeter in diameter. Normally the cells are in the form of disks, both sides of which are concave.

Red blood cells are developed in the red marrow, found in the ends of the long bones and throughout the interior of flat bones, such as the vertebrae and ribs. The cells have definite nuclei in the early stages of their formation. In man and the other mammals the nuclei are lost by the time the cells have become mature and before they are released into the blood stream.

Each mature red blood cell has a structural framework called the *stroma*, which is made up chiefly of proteins and fatty materials. It forms a mesh extending into the interior of the cell. It gives the cell its shape and flexibility.

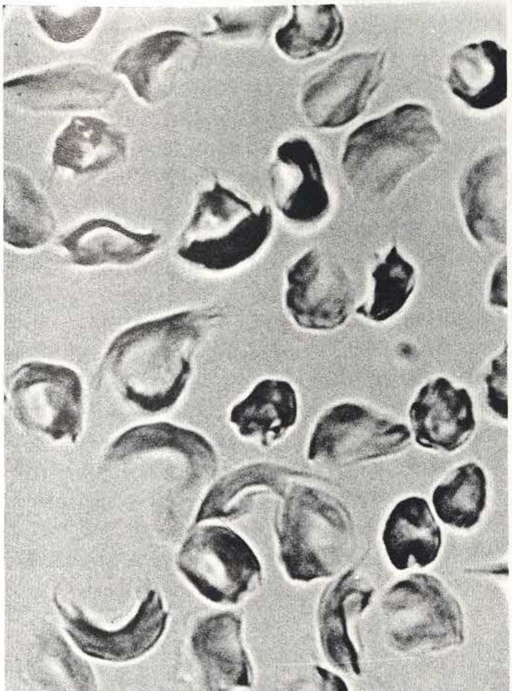
The most important chemical substance in the cell is *hemoglobin*, which causes blood to have a red color. Hemoglobin is composed of an iron-containing pigment called *heme* and a protein called *globin*. There are about four parts of heme to ninety-six parts of globin. In a man the normal amount of hemoglobin is 14 to 15.6 grams per 100 cubic centimeters of blood; in a woman it is 11 to 14 grams.

Hemoglobin combines with oxygen in the lungs after air has been inhaled; the resulting compound is called oxyhemoglobin. When the red blood cells later make their way to other parts of the body deficient in oxygen, the oxygen in the compound breaks its bonds and makes its way by diffusion to the tissues of the oxygen-poor areas. Thus the red blood cells draw oxygen from the lungs, transport it in the blood stream, and release it to the tissues as needed. In high altitudes the rarefied air contains less oxygen, so the body needs more red cells to carry the needed amount of oxygen to its cells. Therefore, within limits, the higher the altitude, the more hemoglobin there is.

The average life span of a red blood cell is 110 to 120 days. Worn-out cells are destroyed by the spleen. The remnants are transported to the liver, which stores the iron they contain. Eventually, the iron passes to the marrow of the bones, where new red cells will be formed. In the healthy indi-

Sickle-cell anemia is a disease in which the red blood cells have an abnormal sickle shape and do not function normally.

B. Gefroy



vidual, the rate of formation of red cells in the bone marrow keeps pace with the rate of destruction.

RED CELL COUNT

It is sometimes very important in making a medical diagnosis to determine the number of red blood cells and also the hemoglobin content of the blood. To count cells, the blood is diluted by a carefully measured amount of 0.9 per cent sodium-chloride solution, and then the red cells are counted one by one in a tiny glass compartment within a counting chamber. The dimensions of the compartment are 1/20 millimeter by 1/20 millimeter by 1/10 millimeter. Its capacity, therefore, is 1/4,000 cubic millimeter. After one finds out the number of red cells in this amount of diluted blood, it is a relatively simple matter to calculate the number of cells in a cubic millimeter of undiluted blood. This test can be misleading unless the diagnostician considers that while the count may be normal, the individual cells may be lacking in an adequate amount of hemoglobin.

Various methods are used to determine the hemoglobin content of the blood. Most of these depend on the color of the hemoglobin. Sometimes a drop of blood is drawn and compared with a chart containing various shades of red or pink. Each of these shades represents a certain color of blood and this color corresponds to a known quantity of hemoglobin.

A more accurate method requires the use of a spectrophotometer. A sample of the blood is mixed with ammonium hydroxide and then shaken, the hemoglobin thus being converted into oxyhemoglobin. This pigment is then measured by means of the spectrophotometer.

Another test used in the study of the red blood cells is the *hematocrit reading*, which gives an estimate of the volume of packed red cells in relation to the volume of the plasma. First an oxalate (a salt of oxalic acid) is added to the blood to prevent its clotting. A sample of blood is then inserted into a hematocrit tube, closed at one end and graduated in millimeters, and the tube is whirled, or centrifuged. The red cells become packed in the bottom, since they are heavier than the plasma. If the level reached by the packed cells is lower or higher than the normal reading, it may indicate disease. From the hematocrit reading, it is possible to figure the volume and hemoglobin content of the average red cell and the concentration of the hemoglobin in the red-cell mass. This test is usually more accurate than measuring the hemoglobin.

A doctor may also want to know the *sedimentation rate* of the red blood cells. The oxylated blood is placed in a hematocrit tube and left standing upright in a rack for a certain period. The red cells sink because they are heavier than the plasma in which they are suspended. The rate at which they fall may be hastened or slowed by abnormalities. The principal factors influencing the sedimentation rate are the concentrations of the proteins. After sedimentation has taken place, the blood is centrifuged in order to pack the red blood cells tightly. Then the hematocrit is read.

The red blood cells may also be examined on a slide. A drop of blood is smeared on a slide, dried, and then stained. The technician can tell whether the cells are abnormal in shape, in hemoglobin content, and in other respects.

WHITE BLOOD CELLS

The white blood cells are the body's military force, attacking disease organisms such as staphylococci, streptococci, and meningococci bacteria. These cells are far less numerous than the red variety. The proportion of white to red under normal conditions is 1 to 400 or 500. The white blood cells are semitransparent bodies. They differ from red cells in several important respects. Among other things, they contain no hemoglobin and they always have nuclei.

There are several easily distinguished varieties of white cells: *neutrophils, lymphocytes, basophils, eosinophils,* and *monocytes*. Neutrophils, basophils, and eosinophils are formed in the bone marrow. Lymphocytes are made in the lymphatic tissues. Monocytes are formed in the reticuloendothelial system. All white blood cells have a life span of less than two weeks.

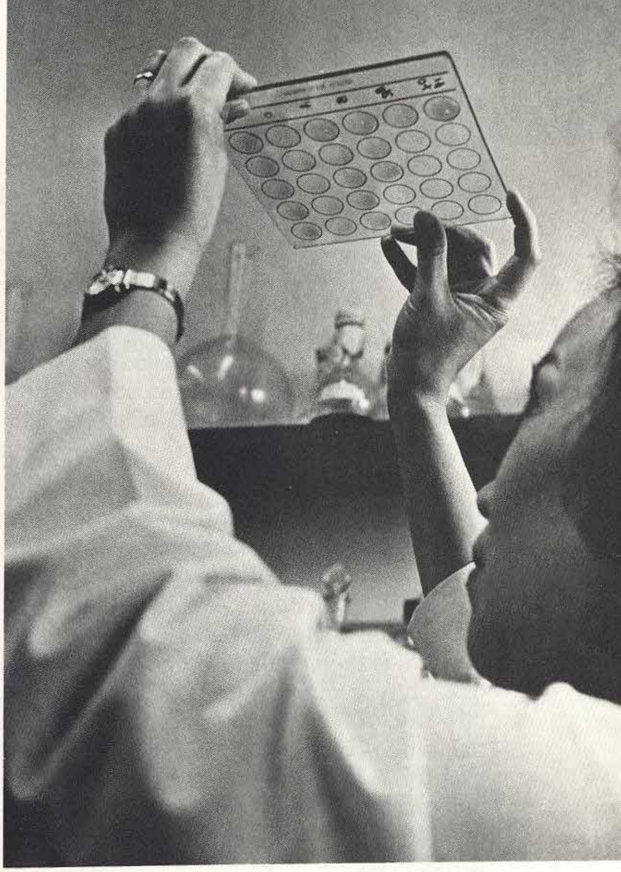
Neutrophils. The neutrophils are by far the most numerous of the white blood cells, making up from 65 to 70 per cent of the total. They derive their name from the fact that they readily take the color of a neutral dye. These cells are about half as large again as red blood cells.

When germs infect the body, they begin to destroy the tissues because of the poisons they liberate. The nearby blood vessels begin to dilate and quantities of blood flow into the area. The neutrophils migrate in great numbers to the affected region and make their way through the walls of the expanded blood vessels. They then attack the invading bacteria and engulf them. They also absorb fragments of body cells that have succumbed to the invading organisms. Many of the neutrophils are killed by bacterial poisons. In dying, they release digestive enzymes, which serve to break up nearby dead cells.

As a result of all this activity, the area of the infection becomes swollen with blood, tissue fluids, dead cells, living and dead bacteria, and neutrophils and various kinds of cell fragments. All these elements form a thick semiliquid mass called *pus*. A large accumulation of pus is called an *abscess*.

As more and more neutrophils are drawn into the struggle against the invading organisms, the formation of neutrophils in the bone marrow is speeded up. The result is that there is a notable increase in the number of white cells in the blood. This condition is called *leukocytosis*. This fact gives the physician an important tool for diagnosing pneumonia, appendicitis, peritonitis, mastoiditis, and other diseases. In these diseases the white-cell count may rise from the normal 5,000 or 10,000 per cubic millimeter to 15,000 or 20,000 or, in extreme cases, to 50,000. In most cases the additional white cells are neutrophils.

Lymphocytes. The white blood cells known as lymphocytes are second only to the neutrophils in number. They make up from 20 to 25 per cent of the white cells. They are found in large numbers in the lymph nodes and spleen. It is thought that lymphocytes are transformed into connective-tissue elements, which aid in the healing process. Some authorities believe that lymphocytes may release antibodies.



Many procedures to determine the condition of the blood have been developed. In some the color of a sample of blood is compared to a standard chart.

Basophils. The basophils (0.5 to 1 per cent of the white-cell total) are so called because they have an affinity for a basic dye called methylene blue. Basophils secrete an anticoagulant, called *heparin*. Heparin is a normal part of the blood. It plays a role in preventing clots within blood vessels.

Eosinophils. The eosinophils (2 or 3 per cent), which are easily stained with the dye called eosin, increase in number in some diseases, particularly allergic infections such as hay fever and asthma, and in certain parasitic conditions, including hookworm and trichinosis.

Monocytes. The white blood cells known as monocytes (5 to 12 per cent) are active little cells, moving around in the blood stream at a great rate. They act much like amebas, pushing out their pseudopodia and enveloping debris resulting from infection. They seem to form part of the body's defense against microorganisms, and are especially active in tuberculosis, malaria, and typhoid. Monocytes are the largest of the white blood cells. They are two or three times as large as red blood cells.

WHITE CELL COUNT

Since the proportions of the different white cells in the blood can indicate some abnormality, the doctor may want to know what percentages of each are present. This is determined by what is called a *differential white-cell count.* A drop of blood is smeared on a slide and is dried and stained. A count is then made of the actual numbers of each type of white cell out of a given total—say, 100. In some reports of differential white-cell counts, the percentage of each type of white blood cell is given. In others, the number of each type per cubic millimeter of blood is calculated.

PLATELETS

Platelets are tiny circular or oval disks, which are derived from certain giant cells in the bone marrow, called *megakaryocytes.* Their number ranges from 200,000 per cubic millimeter to 500,000 or more. The platelets, which are much smaller than the blood cells, serve several useful purposes. When they disintegrate, they liberate a substance called *thrombokinase* or *thromboplastin,* which is vital in the blood-clotting process. They also help to plug leaks in the tiny blood vessels called capillaries.

A doctor who suspects the platelets of being abnormal may want to examine the blood for them. This, also, is best done with a stained slide. Exact counts of platelets are difficult to do with accuracy because the little cells tend to clump together. Doctors usually consider it sufficient if several clumps are seen in nearly every field observed under a microscope. Of course this tendency to stick together is one thing that makes the platelets so useful. They act in this way when they plug up little holes in capillaries. Platelets live for only a few hours.

CLOTTING

Blood is so vital that the loss of a considerable quantity would have the direst consequences. Fortunately for us, nature has provided a means of stanching the flow from ruptured blood vessels through the process known as *coagulation,* or clotting.

In clotting, the blood is first converted into a jellylike mass. As the process continues, threadlike structures, which are composed of *fibrin,* form a tangled mesh. The formed elements of the blood—red and white blood cells and platelets—are trapped in the meshes. As the clot solidifies, it shrinks and serum is squeezed out from it. The red color of the clot is due to the red blood cells that have been captured between the interlacing strands of fibrin. These cells have nothing whatever to do with the clotting process.

Fibrin is not present in the blood. It is formed through the union of two substances called *fibrinogen* and *thrombin.* Fibrinogen is always present in the plasma. Thrombin is not always present, though the plasma contains an inactive form of thrombin called *prothrombin.* Vitamin K is necessary for the formation of prothrombin and several other blood factors.

A rather complicated train of events occurs before fibrin appears. First, the injured tissues liberate a clot-inducing substance called *thrombokinase.* This is also freed by the disintegration of platelets. Thrombokinase then reacts with the prothrombin present in the plasma, in the presence of calcium ions (electrically charged calcium atoms), to produce thrombin. Finally thrombin and fibrinogen react to produce fibrin, which then enmeshes to form the clot. Blood normally clots in one to five minutes in the case of a superficial flesh wound. Much more time is required if the wound is deep.

BLOOD DISEASES

A number of illnesses are characterized by some abnormality in the blood.

Anemias. In some cases, the red blood cells are seriously reduced in number or else they are deficient in hemoglobin. We then have the condition known as *anemia*—or, more correctly, the anemias. Because of the hemoglobin deficiency, less oxygen reaches the tissues and the cells cannot function normally. Among the symptoms are pallor, fatigue, headache, general weakness, black spots before the eyes, palpitation of the heart, and an increased pulse rate. In severe cases, breathing may be shallow and difficult. Occasionally there is an excessive amount of water in the tissues. This is usually due to poor circulation, since the heart muscle is not getting enough oxygen. In some instances a person may be anemic without displaying any of these symptoms.

There are various types of anemias. The *nutritional anemias* are due to some malfunctioning of the blood-forming centers. Enough of the materials necessary for blood formation may not be present in the diet, or the body may not be able to utilize those materials. If enough iron is not taken in, for example, an iron-deficiency anemia may develop. The red blood cells will be smaller than is normal, perhaps fewer in number, and they may have less hemoglobin than usual. They will not be able to carry enough oxygen and so an oxygen deficiency will develop in the tissues. Women are particularly likely to develop this kind of anemia. Another nutritional anemia, causing similar symptoms, is *achlorhydric anemia.* In this disease, not enough hydrochloric acid is secreted in the stomach. This prevents absorption of iron, even though there may be enough in the diet.

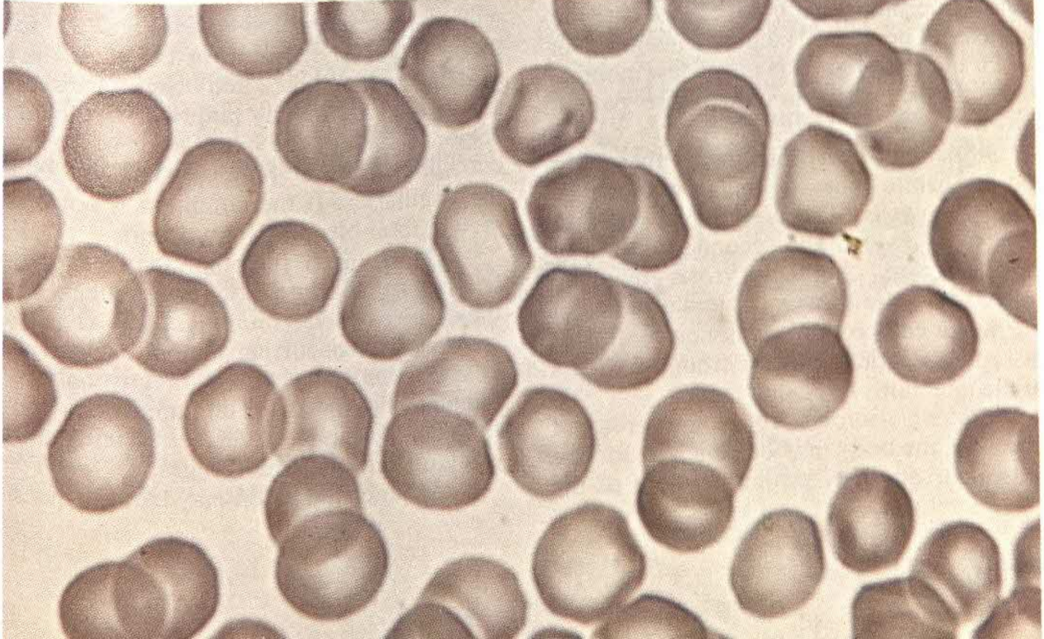
In *hemolytic anemias,* the circulating red blood cells are destroyed too quickly. This may be either an inherited or acquired characteristic. It may be due to overactivity of the spleen, to the effects of certain poisons, or to the fragility of the red blood cells. In certain cases, it may be necessary to remove the spleen.

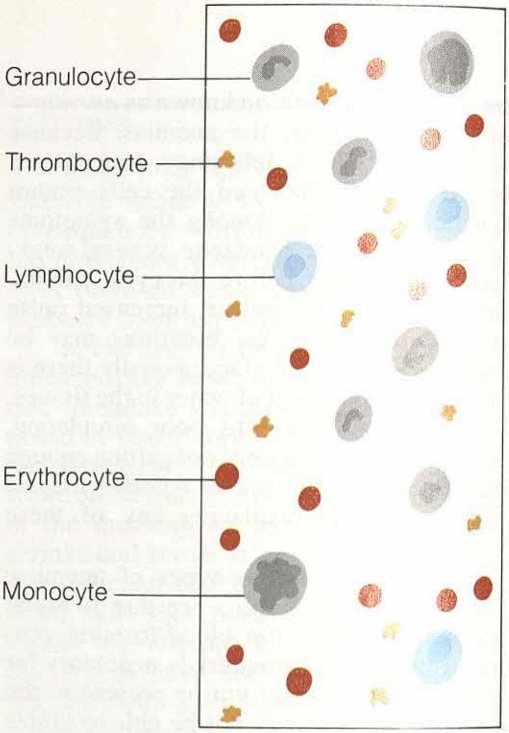
The disease known as *pernicious anemia* is particularly serious. People with pernicious anemia lack a certain enzyme-like substance in the gastric juice. This substance is necessary if the body is to absorb cyanocobalamin, or vitamin B_{12}, and be able to produce red blood cells. They must be given vitamin B_{12} by injection, since they cannot absorb it through the normal processes of digestion. Death occurs in two or three years after the disease begins if the treatment is not applied.

Certain anemias are secondary—that is, they result from some underlying condition, which may or may not be clearly defined. Such anemias may be a consequence of hemorrhage, chronic blood loss,

Red blood cells seen under the electron microscope. In the anemias, there are too few or abnormal red blood cells. In polycythemia, there are too many.

B. Gefroy





HUMAN BLOOD CELLS

A number of diseases can be diagnosed by a change in the number, shape, or size of the various blood cells.

acute infection, malignant growths, gastrointestinal disease, or damage to the liver. X rays and various toxic and radioactive substances may cripple the bone marrow so that it is unable to produce an adequate number of red blood cells.

Polycythemia. A serious disorder, *polycythemia,* is characterized by an overproduction of red blood cells. The blood becomes too thick and moves through the veins sluggishly. The patient complains of headaches and dizziness and has a tendency to form clots in the blood vessels. If these clots drift around in the veins and arteries, they may cause gangrene, or tissue death, to develop. Clots that plug up a vessel in the heart or brain may cause death. The patient is bled at regular intervals and may be given a drug to slow down the red-cell production.

Leukemia. In some illnesses there is an overproduction of white blood cells. This is sometimes due to the disease known as *leukemia,* in which the white-cell count may reach the amazing total of 500,000 per cubic millimeter. The white cells overrun the bone marrow, crowd out the red-blood-cell and platelet-producing material, and cause an accompanying anemia to develop. Lymph nodes and reticuloendothelial tissue swell with their burden of excessive white cells. Leukemia is believed to be due to an abnormal condition of the bone marrow or lymphoid tissue, causing white-cell-forming elements to multiply. Treatment can prolong life, but it cannot cure the disease. There are acute leukemias in which life expectancy is only a few months, and chronic cases in which the patient may live years.

Agranulocytosis. Sometimes there are too few white cells – a condition known as *agranulocytosis.* The body's resistance to disease is lowered and secondary infection may develop. Agranulocytosis may be caused by toxic substances and diseases of the white-cell-producing tissues. With this disorder, a patient may die from the effects of the infections he cannot resist.

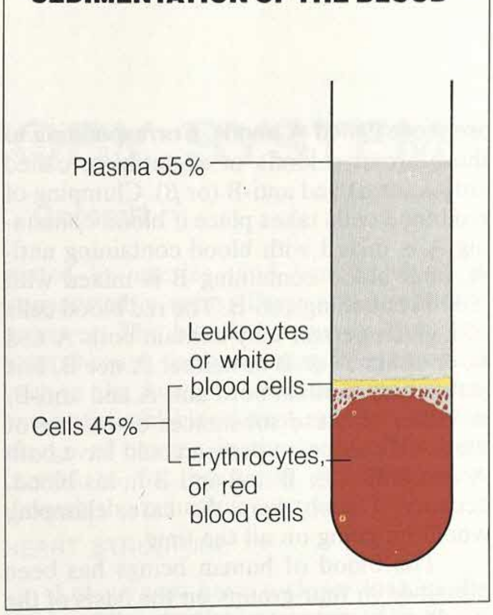
Clotting disorders. In another group of diseases, the body may be deficient, for one reason or another, in one or more of the essential clotting elements. Platelets may be defective or too few in number; the fibrinogen content of the plasma may be seriously reduced; or there may be a prothrombin deficiency, brought about by a lack of vitamin K. If any of these conditions are present, even slight wounds may cause dangerous bleeding.

In *thrombocytopenia,* a disease in which there are too few platelets, the blood tends to seep out of the circulatory system, making black and blue bruise spots and *petechiae,* or tiny pinprick-sized blood spots. This happens because there are not enough platelets to plug up small breaks in the capillaries. If the condition is not corrected, fatal bleeding may occur.

The failure of the blood to clot properly has particularly serious consequences in the disease called *hemophilia.* It is a hereditary disease, occurring almost exclusively in males and transmitted directly only by females. The most trivial happening – friction on the gums, a very slight cut – may bring on serious hemorrhages.

At times the blood may clot too quick-

SEDIMENTATION OF THE BLOOD


Plasma 55%
Leukocytes or white blood cells
Cells 45%
Erythrocytes, or red blood cells

The different components of the blood settle at different rates. Changes in the normal sedimentation rate can indicate an abnormality.

ly. A clot, called a *thrombus*, may form upon the wall of a ruptured blood vessel. It may extend completely across the vessel in such a way as to shut off the flow of blood. If this vessel supplies blood to a vital body structure, the consequences may be most serious. Death may result unless nearby blood vessels can take over the task of supplying blood to the affected areas.

In some cases a thrombus may break loose from a blood vessel. It may be carried off in the blood stream to another blood vessel, which it may partly or wholly block up. A foreign or abnormal particle of any kind carried in the blood stream in this way is called an *embolus* (plural: emboli). If an embolus is transported by the blood stream in the veins to the right side of the heart it may block up the pulmonary artery, wholly or in part. Death results if the artery is entirely obstructed. If the stoppage is only partial, gangrene or inflammation of part of the lung commonly takes place. Emboli may block up arteries in other parts of the body and may result in the shutting off of the blood flow in these areas. If the embolus is septic—that is, poisoned by bacteria—it would cause infection wherever it is lodged and may lead to *pyemia*, a kind of blood poisoning.

BLOOD GROUPS

Each person's blood possesses certain inherited characteristics which distinguish it from the blood of every other person. On the basis of these characteristics, human blood is divided into different groups. Scientists came to understand the groups when they studied blood transfusion.

In blood transfusion, blood from an outer source is introduced into the veins of a person in order to replace lost blood, or to prevent shock, or to combat infection, or to treat certain other conditions. Formerly anyone willing to contribute his blood was accepted as a donor. Doctors were puzzled by the serious aftereffects that sometimes occurred. The red blood cells of certain donors would form clumps after transfusion.

We now understand, thanks to the researches of pathologist Karl Landsteiner and others, why these effects occur. They are due to substances called *agglutinogens*, or *antigens*, which occur in the red blood cells, and also to *agglutinins*, the antibodies that originate in the serum of the blood. A certain variety of agglutinin will cause red blood cells to clump if these cells contain a certain variety of agglutinogen.

Two important types of agglutinogens

Name of group	Agglutinogens in red blood cells		Agglutinins in serum		Percentage of Caucasoids belonging to group	Percentage of Negroids belonging to group	Percentage of Mongoloids belonging to group
	A	B	anti-A	anti-B			
Group O	none	none	present	present	40%	42%	29%
Group A	present	none	none	present	45%	24%	42%
Group B	none	present	present	none	10%	28%	20%
Group AB	present	present	none	none	5%	6%	9%

are those called A and B. Corresponding to these are two kinds of agglutinins, called anti-A (or α) and anti-B (or β). Clumping of red blood cells takes place if blood containing A is mixed with blood containing anti-A, or if blood containing B is mixed with blood containing anti-B. The red blood cells of a given person may contain both A and B, or either A or B or neither A nor B. His serum may contain both anti-A and anti-B, or either of these substances or neither of them. Of course no person could have both A and anti-A or B and anti-B in his blood, because if such were the case, clumping would be going on all the time.

The blood of human beings has been classified in four groups on the basis of the A, B, anti-A, and anti-B factors. These groups are known as O, A, B, and AB.

Rh FACTOR AND OTHERS

There are also other blood groupings. One that also has an important bearing on blood transfusion is based on the so-called *Rh factor*, an agglutinogen found in the red blood cells of most people. It is called the Rh factor because it is similar to an agglutinogen found in the red blood cells of the rhesus monkey. Blood possessing the Rh factor is called *Rh-positive*. Blood without this agglutinogen is known as *Rh-negative*.

If blood from an Rh-positive person is transfused into an Rh-negative person, the serum of the latter will produce an anti-Rh agglutinin. If the patient receives another Rh-positive transfusion, the anti-Rh agglutinin will cause the red blood cells contributed by the donor to clump as soon as they enter the recipient.

Blood typing is based on the antibody-antigen reactions in the blood. The blood shown below is type A. It has clumped because type B has been added to it.

George Whiteley

A similar type of reaction can occur when an Rh-negative woman becomes pregnant with an Rh-positive baby, the baby having inherited the Rh factor from its father. During pregnancy some of the red blood cells of the fetus may pass into the mother's blood and cause her body to produce antibodies against the Rh factor. These antibodies can then pass into the fetal blood stream and cause the destruction of red blood cells in a condition known as *erythroblastosis fetalis*. This reaction does not usually occur in a first pregnancy unless the woman has previously built up Rh antibodies, but subsequent pregnancies in which the fetus is Rh positive do present a problem. However, highly successful treatments are now available to prevent such problems and to cure them if they occur.

Many other blood groups have become known; many different combinations of all the factors are possible. These factors account for the complexity and individuality of each person's blood.

TRANSFUSIONS

Knowledge of the different blood groups has made blood transfusions a relatively safe procedure. Tests for the O, A, B, and AB groups and for the subgroups are made before a transfusion. The donor and the recipient should belong to the same main group. In case of extreme emergency, group-O blood may be given to patients of any group, and AB patients may be given blood from any of the three other groups. For this reason, Group O is known as the *universal donor* group, and AB is called the *universal recipient* group.

In many cases human plasma is used for transfusions, particularly to replenish deficiencies in blood proteins, to build up or maintain blood volume, and to treat shock. The great advantage of this type of transfusion is that plasma from any donor may be used, and plasma can be safely stored for long periods and easily transported. The plasma fraction *serum albumin* has proved particularly effective in shock.

THE CIRCULATORY SYSTEM

by Chalmers L. Gemmill

Blood is carried to every part of the body in an intricate system of tubes that make up the *circulatory system*. This system consists of a pump—the *heart*—and a network of blood vessels—*arteries, capillaries*, and *veins*. All arteries lead from the heart. All veins lead to the heart. Arteries and veins are connected by capillaries.

Briefly, this is what happens as blood circulates. Part of the blood in the heart has just received a fresh store of oxygen from the lungs. This blood is pumped into a large artery—the *aorta*. From the aorta it is carried into a branched system of smaller arteries. From the arteries it passes into the capillaries. Here the blood gives up oxygen and food materials, which have been absorbed from the small intestine and liver, to the tissues. Waste materials, including the gas carbon dioxide, are received. The blood, now *deoxygenated*, then passes to the veins. It is returned to the heart by way of two large veins.

The blood is then pumped from the heart through the large *pulmonary artery* to the lungs. In the lungs carbon dioxide is discharged and oxygen is received. The oxygen-laden blood is then returned to the heart through the *pulmonary veins*, and another cycle begins.

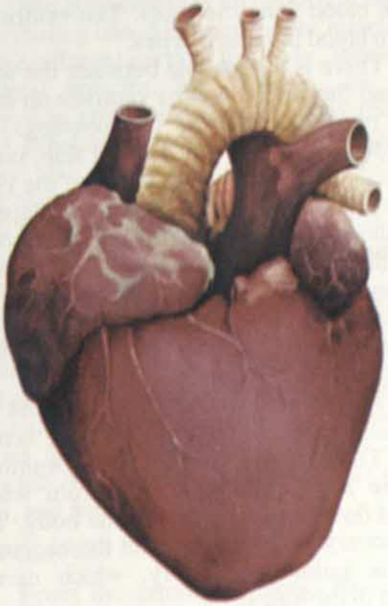
There are two major circulation systems in the body. In the *greater*, or *systemic, circulation*, blood is transported from the heart to every part of the body and back to the heart. In the *lesser*, or *pulmonary, circulation*, blood travels from the heart to the lungs and from the lungs to the heart. There are various minor systems, such as the *hepatic circulation*, through the liver, and the *cerebral circulation*, through the brain.

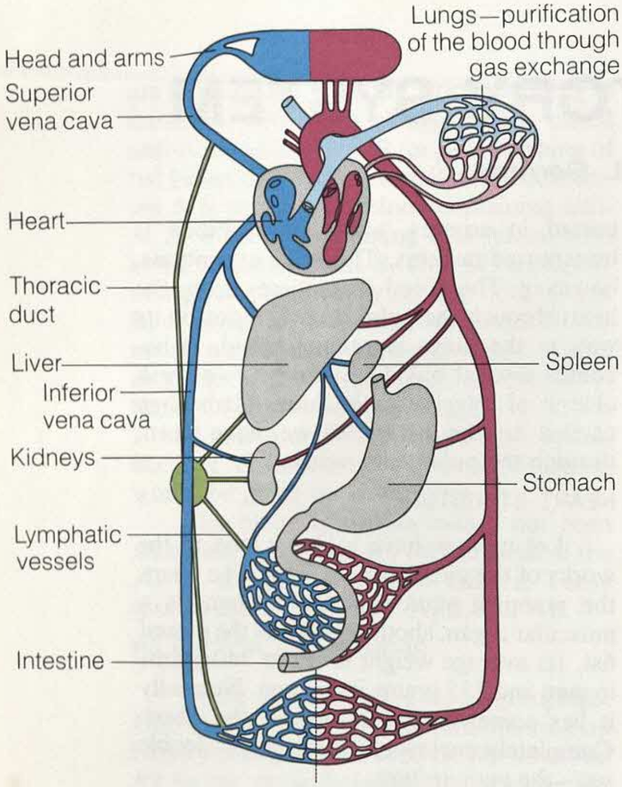
The blood that has received fresh supplies of oxygen from the lungs is called *arterial blood*. The name *venous blood*, or deoxygenated blood, is given to blood that has passed through the capillaries and has become charged with carbon dioxide. Generally speaking, arterial blood is transported in arteries, and venous blood is transported in veins. There are exceptions, however. The blood that passes from the heart through the pulmonary arteries on its way to the lungs is venous blood. It becomes arterial blood as it receives a fresh charge of oxygen in the lungs. It is then carried to the heart, as we have seen, through the pulmonary veins.

HEART STRUCTURE

Let us now have a closer look at the works of the circulatory system. The heart, the pumping station of the system, is a muscular organ, about as large as the closed fist. Its average weight is about 340 grams in men and 255 grams in women. Normally it lies somewhat to the left in the chest. Completely enclosing the heart is a double sac—the *pericardium*.

External view of the normal human heart. This muscular organ is the pump for all the intricate tubing of the circulatory system.





SYSTEMIC AND PULMONARY CIRCULATION

A wall, called the *septum,* divides the heart into a left half and a right half. Each half, in turn, is divided into an upper chamber – the *auricle,* or *atrium* – and a lower chamber – the *ventricle.* The auricles receive blood from the veins. The ventricles pump blood into the arteries.

There is an opening between the auricle and the corresponding ventricle on each side of the heart. The two openings are guarded by *valves,* made up of thin, membranous flaps. The valve between the right auricle and right ventricle has three flaps. It is called the *tricuspid valve.* There are only two flaps in the valve between the left auricle and left ventricle. This is called the *bicuspid valve.* It is also known as the *mitral valve,* because with its two flaps it looks something like a bishop's miter.

Two other valves, the *aortic* and the *pulmonary,* guard the exits from the ventricles. The aortic valve is set at the beginning of the aorta, the big artery from which blood flows to every part of the body. The pulmonary valve is located at the beginning of the pulmonary artery, which carries blood to the lungs.

HEART ACTION

Each pumping action of the heart consists of two phases – *systole* and *diastole.* The heart contracts in systole. It relaxes in diastole.

During the relaxing phase, blood – deoxygenated blood – enters the right auricle from two big veins, the *superior vena cava* and the *inferior vena cava.* The superior vena cava leads from the head, neck, and arms; the inferior, from the abdomen, pelvis, and lower limbs. At the same time that blood is flowing into the right auricle from the venae cavae, other – freshly oxygenated – blood is entering the left auricle from the pulmonary veins, leading from the lungs.

The valves between the auricles and ventricles on both sides of the heart open. Blood rushes into the ventricles. When these are quite filled, or nearly filled, the auricles contract and empty their contents into the ventricles, giving an extra thrust to the blood. This is the start of systole. The ventricles contract in their turn. As they do so, the valves between the ventricles and the auricles close. For a time each ventricle, still contracting, forms a closed container for blood, since the valves on either side of it are shut.

Finally the aortic valve and the pulmonary valve, shutting off the ventricles from the arteries, are forced open. Blood spurts from the right ventricle to the pulmonary artery and is sent on its way to the lungs. At the same time, blood is forced from the left ventricle into the aorta. From here it will be transported by way of the other arteries to the different parts of the body. The ventricles relax, and diastole sets in. The aortic and pulmonary valves then close.

BLOOD FLOWS INTO ARTERIES

The arteries, into which the ventricles pump blood, are tough and elastic vessels. Their walls are made up of three coats. The inner coat consists of a delicate and thin cellular lining. The middle one is much thicker. It is made up of smooth muscle fibers and elastic connective tissue. The connective tissue of the outer coat bears nerves and small blood vessels.

Generally the arteries are overfilled with blood and therefore their walls are somewhat stretched. They are stretched still more when the ventricle ejects blood into them. During the relaxing phase, or diastole, the walls of the arteries contract. As they do so, they press upon the blood and force it along the arterial system.

Let us follow the course of the blood as it leaves the left ventricle and enters the aorta, from which it will circulate throughout the body. As we have seen, it is now rich in oxygen. This gas, absorbed in the lungs, has combined with the *hemoglobin* in the red blood cells, to form a compound called *oxyhemoglobin.* Because of the renewed supply of oxygen, the red blood cells are now bright scarlet, and they impart this color to the blood.

ARTERIES TO ARTERIOLES

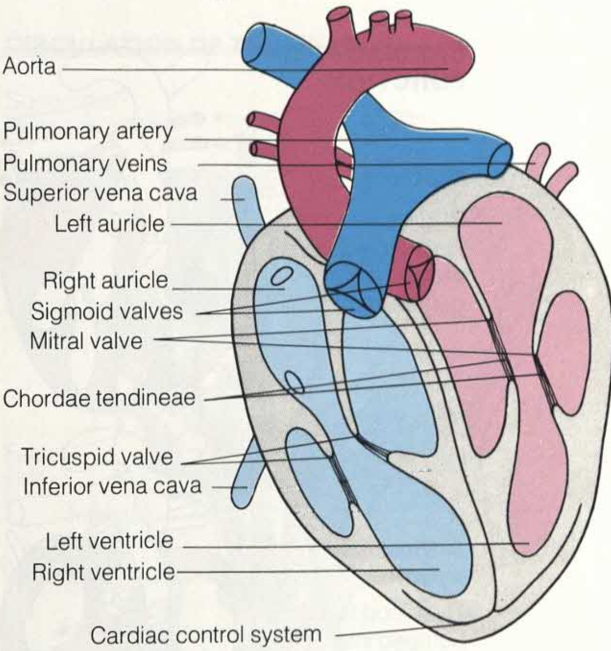
The aorta, the first and largest of the arteries, is more than two and one-half centimeters in diameter at the place where it begins at the upper part of the left ventricle. Two arteries, leading from the aorta near its base, supply the heart muscle itself with blood. They are called the *coronary arteries.*

Beyond the coronary arteries the aorta forms an arch about five centimeters high. Three large arterial branches lead from the top part of the arch. They are the *innominate, left carotid,* and *left subclavian arteries.* Blood flows through them to arteries in the head, neck, upper limbs, and chest. The descending part of the aortal arch, passing near the vertebral column, leads from the chest cavity into the abdominal cavity. There are branches from this part of the aorta to the intestines, kidneys, and other organs of the abdomen. The descending aorta finally divides into two terminal branches. These are the right and left *iliac arteries,* which carry blood to the legs.

As they branch out, the arteries grow smaller. The tiniest tubes in the arterial system are not much thicker than hairs. They are only about 0.2 millimeter in diameter. These blood vessels are called *arterioles,* or little arteries. They are plentifully supplied with encircling smooth muscle. When the muscle fibers contract, they reduce the diameter of the arterioles, or close them off entirely. The diameter of the arterioles is increased when the muscle fibers relax.

NORMAL HEART
of a young person

Vertical section through the heart



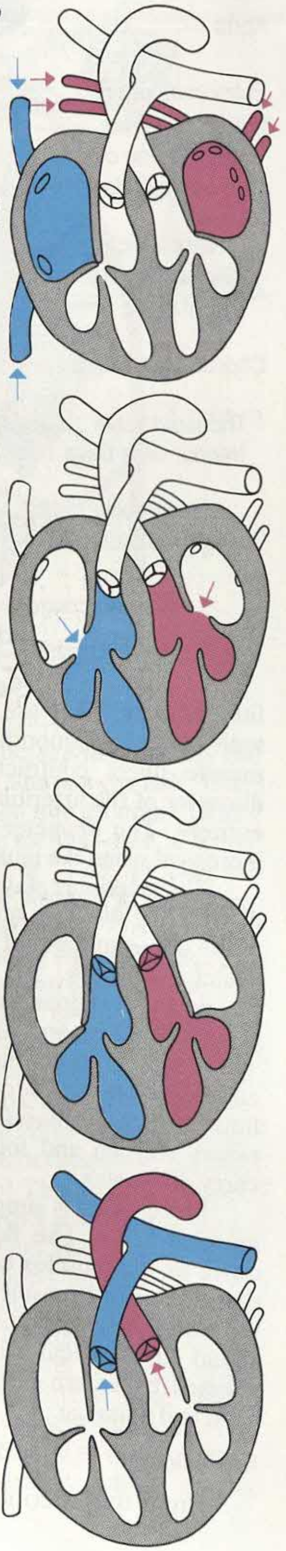
The arterioles play an important part in distributing blood in appropriate quantities to the different parts of the body. When the skeletal muscles, for example, are employed in strenuous exercise, they use up food substances and oxygen more rapidly. They also produce more carbon dioxide and other wastes. More blood must then flow through the muscles to supply the necessary oxygen and food materials and to carry off wastes.

More blood is supplied as the arteriole muscles relax. The flow of blood is cut down as the muscles contract. The nerves that trigger this muscle action form part of the autonomic nervous system. They respond to chemical stimuli, and are also affected by external stimuli such as cold, heat, and massage.

CAPILLARIES

From the arterioles, blood flows into

CARDIAC PUMP FUNCTION



Diastole

Passive filling of the auricles, then of the ventricles; general rest

Auricular systole

The blood is pumped into the ventricles

Ventricular systole

first time: closing of the atrioventricular valves

Ventricular systole

second time: Ejection of ventricular blood into the circulation

the capillaries. These are the finest of all blood vessels. Their diameter is only about 0.02 millimeters. The capillaries form an intricate network of connecting channels. Though each of the blood vessels in the network is tiny, their combined capacity is greater than that of the arteries, and they offer a wider channel for the passage of blood. As a result, the flow of blood through the capillaries is comparatively slow.

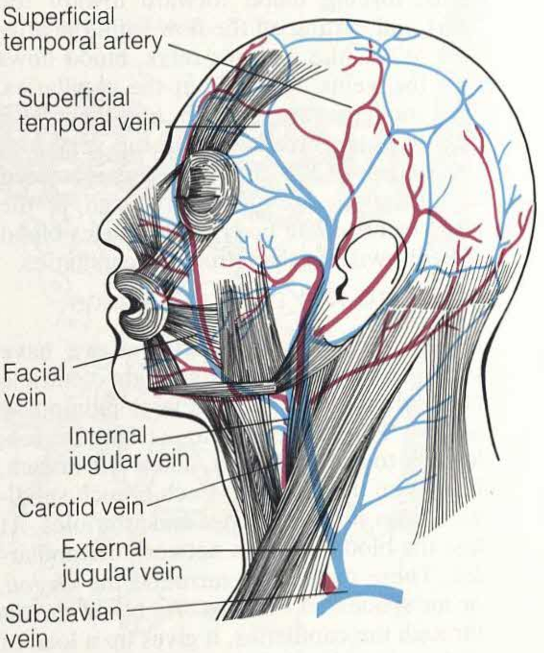
As we pointed out, the exchange of materials between the blood and the tissues of the body takes place only in the capillaries. Their walls are made up of a single layer of cells and are porous. They allow fluid to pass from the blood and to mix with the fluid present in the tissues. They also permit tissue fluid to enter the capillaries and to mix with the blood.

The exchange of materials is brought about by diffusion through the capillary walls. Suppose that a given material is more highly concentrated on one side of these walls than on the other. It will pass through the walls from the area of greater concentration. For example, there is more oxygen in the blood that flows into the capillaries than there is in the tissue fluid. Therefore the oxygen will pass through the capillary walls into this fluid. To do so, it breaks loose from the hemoglobin with which it has been combined in the red blood cells. Dissolved food materials transported by the blood will also pass into the tissue fluid.

Food materials and oxygen diffuse into the body cells from the tissue fluid. In the cells food substances are converted into a variety of new materials. Energy is released as food materials are oxidized—that is, as they combine with oxygen. The energy enables the body to carry on its activities. The heat that accompanies energy release helps maintain body temperature.

Carbon dioxide is one of the end products when food materials are oxidized. It passes from the cells to the tissue fluid and from the tissue fluid into the capillaries. Various wastes, such as urea and uric acid, also make their way from the cells to the capillaries. They are carried in the blood to the kidneys and are later passed from the body in the urine.

CIRCULATION OF THE HEAD



Arteries and veins branch out, forming a complex network throughout the body, as this diagram of just a part of the body shows.

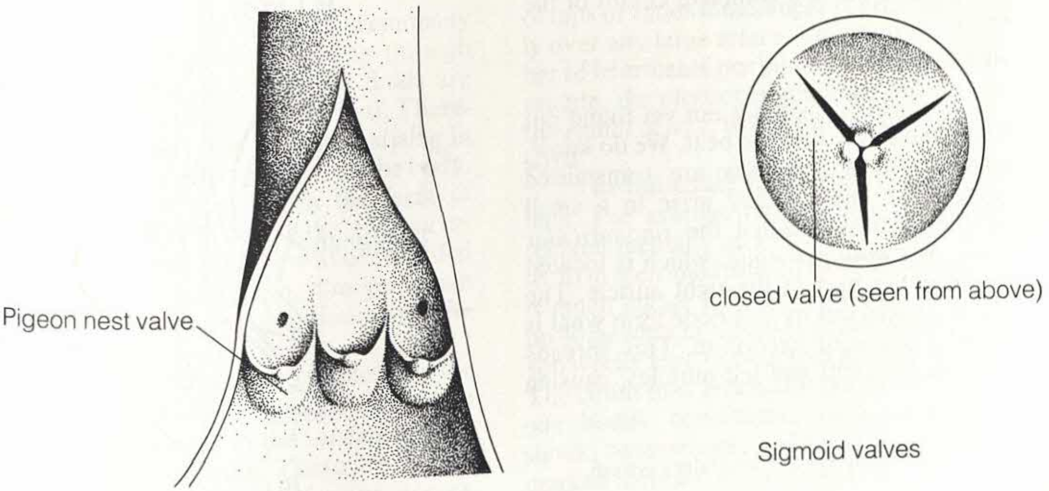
The diameter of the capillaries can be decreased or increased. The capillaries nearest the arterioles are provided with smooth muscle. As this contracts or dilates, it helps control the quantity of blood passing through the capillaries. Changes in the diameter of the arterioles and capillaries account for various changes in the color of the skin. For example, when they are dilated and filled with blood, the face becomes hot and flushed. When they contract, the face becomes pale and cool.

BLOOD FLOW IN VENULES AND VEINS

The blood passes from the capillaries to very small veins, called *venules*. By this time the red blood cells have given up a part of their oxygen load and as a result they have become dark red. This accounts for the dark red color of venous blood. There are thousands upon thousands of venules. They gradually merge and form larger veins. These combine in their turn. As the blood reaches the larger veins, its speed increases. The venous system ends with the two large veins – the superior and inferior venae cavae – that lead to the right auricle.

The structure of the veins is much like that of the arteries. However, their walls are thinner and have less smooth muscle. Many of the larger veins contain valves that permit the blood to flow toward the heart but not backward toward the arteries. The action of the skeletal muscles helps maintain the flow of blood in the veins. When the

Valves found in the aorta. Left: cross section of aorta, showing open valves. Right: a closed valve as seen from above.



muscles contract, they press upon the veins, forcing blood forward toward the heart and cutting off the flow from the arteries. When the muscles relax, blood flows into the veins again, from the capillaries. The movements made in breathing also help to pump blood through the veins. As the volume of the chest cavity is increased in inhalation, pressure is reduced in the large veins of the body. This causes blood to be drawn into them from the capillaries.

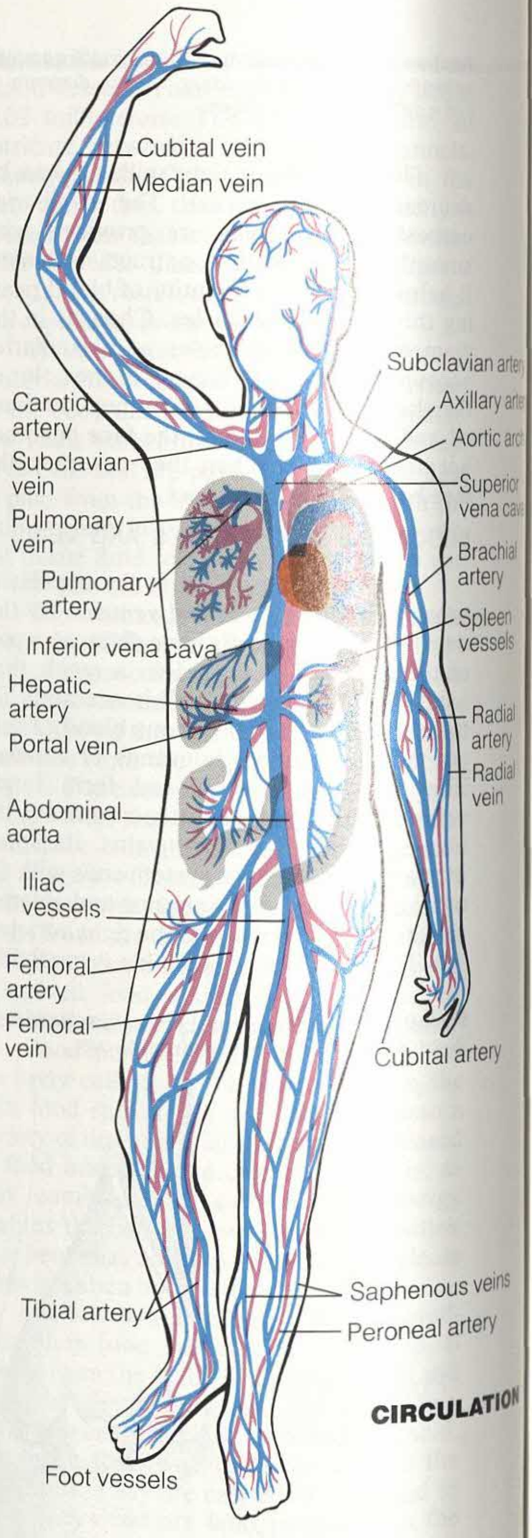
BLOOD TO AND FROM THE LUNGS

From the right auricle, as we have seen, the blood enters the right ventricle and is then forced into the large pulmonary artery. This divides into a right branch, leading to the right lung, and a left branch, leading to the left lung. Each branch subdivides into smaller arteries and arterioles. At last the blood enters a network of capillaries. These capillaries surround the *alveoli*, or air spaces, in the lung. As blood travels through the capillaries, it gives up a load of carbon dioxide. It also releases water to the outer air in the form of water vapor. At the same time the blood receives a fresh load of oxygen.

From the capillaries of the lung, blood flows into small veins, or venules, and from these into larger ones. It makes its way at last into the left auricle through four large *pulmonary veins*. Finally blood flows into the left ventricle, from which it spurts out into the aorta. It takes the blood only about a minute to make a complete circuit of the body.

HEARTBEAT

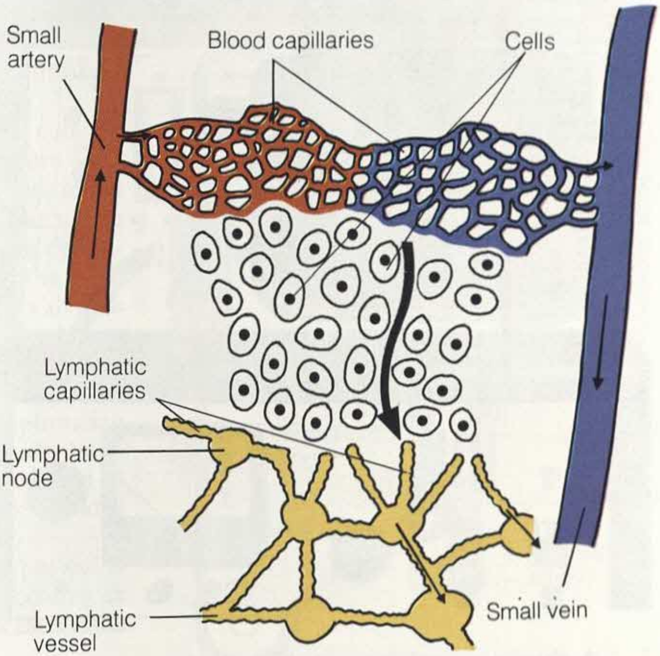
Medical science has not yet found out what causes the heart to beat. We do know, however, how impulses are transmitted within this organ. They arise in a small bundle of tissue, called the *sinoauricular node*, or *sino-atrial node*, which is located in the upper part of the right auricle. The impulses sent out by this node form what is called a *wave of excitation*. This spreads through the right and left auricles, causing



Major blood vessels in the circulatory system.

BLOOD

CONNECTION BETWEEN THE BLOOD AND THE LYMPH CIRCULATORY SYSTEMS



The exchange of materials between the blood and body tissues takes place in the capillaries. Oxygen passes from the arterioles through capillaries to body cells. Waste products pass from body cells through capillaries to veins. Lymphatic capillaries pick up fluid found between body cells and pass it on to the larger vessels of the lymphatic system.

their muscle fibers to contract. The wave of excitation reaches a second node – the *auriculo-ventricular,* or *atrio-ventricular, node* – in the upper part of the wall between the two ventricles. The impulses are then relayed by way of a bundle of tissue to a fiber network, known as the *Purkinje system.* This network transmits the impulses to the muscle fibers of the ventricle and causes them to contract, releasing blood to the arteries.

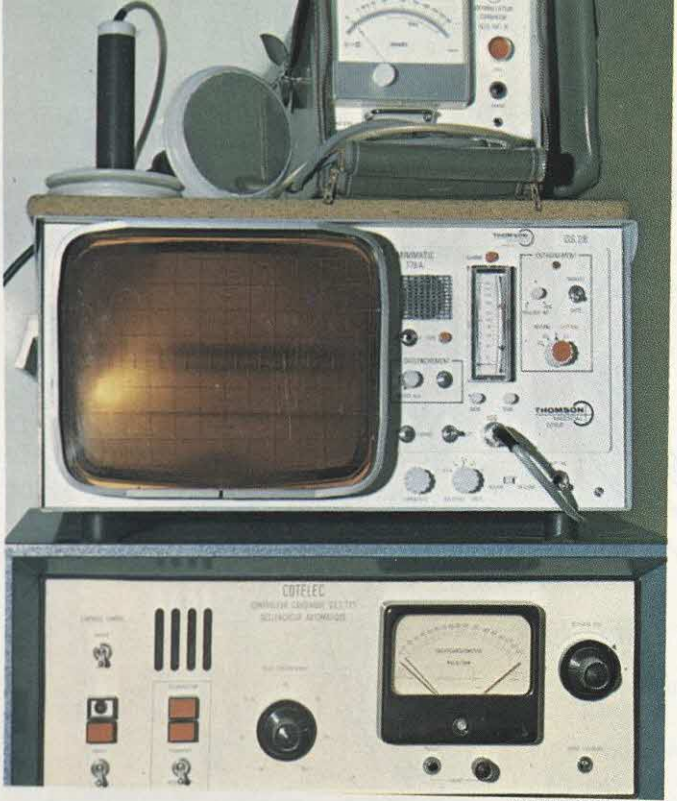
Certain electrical changes accompany the wave of excitation spreading through the heart. The blood and tissue fluids are good conductors of electric current. Therefore changes in electric potential arising in the heart are carried to all parts of the body. Their pattern is recorded in the form of waves in the device called the *electrocardiograph.* By analyzing the waves recorded by the electrocardiograph, the physician can obtain valuable information about the condition of the heart.

The heartbeat is not initiated by the action of nerves, but it is affected by two sets of nerves arising in the *medulla oblongata,* a part of the brain. These are the *vagus nerves* and the *accelerator nerves.* They both belong to the autonomic nervous system. The vagus nerves act as brakes. They slow up the heart and reduce the strength of its beats. The accelerator nerves, on the contrary, speed up the heart and increase the strength of the heart beats.

PULSE

With each heartbeat, a pulse wave spreads all over the arterial system. The succession of waves can be felt as a series of taps or thuds if the finger is pressed lightly over any large artery. To count the number of heartbeats per minute or fraction of a minute, the physician generally presses on the *radial artery,* which passes through the wrist.

The pulse rate varies greatly in individuals. The average rate for adults who are relaxed mentally and physically is from 65 to 70 in men and from 70 to 75 in women. It is much higher in babies. The count slows up somewhat in sleep. It soars when a person works hard or becomes greatly excited. The count may reach 200 per minute. Various bodily conditions, such as surgical shock, hemorrhage, and fever also cause a marked increase in the pulse rate.


Assistance Publique, Paris

In many cases of heart disorder quick treatment is essential to prevent serious damage or death. The instrument shown at left can administer electric shocks to a patient whose heart has stopped beating or is beating very erratically. The beats will be registered on the screen.

A physician applying a stethoscope to a person's chest can generally hear two sounds as the heart beats. The first is softer and lower in pitch than the second, and it lasts longer. It suggests the syllable *lub*. The second sound—something like *dup*—is short and sharp. The two sounds occur in quick succession and are followed by a slight pause. The physician listening to the stethoscope hears something like *lub-dup—lub-dup—lub-dup*.

The *lub* sound is really made up of two sounds that merge. One of these represents the vibrations that arise as the muscle fibers of the heart contract. The other accompanies the closing of the valves between the auricles and the ventricles. The *dup* sound is produced by the vibrations caused by the closing of the aortic and pulmonary valves. Since both the *lub* and *dup* sounds result, in part at least, from the action of the heart valves, the sounds will be distorted if anything is wrong with the valves. The stethoscope, therefore, is valuable in detecting and diagnosing various types of heart diseases.

Sometimes a third sound is heard. It follows the *dup* sound and is very faint. According to one theory it is due to the rapid flow of blood from the auricle to the ventricle. Some authorities hold that it represents a set of "after vibrations"—a sequel to the vibrations heard as the *dup* sound is produced.

BLOOD PRESSURE

As blood is ejected from the left ventricle into the aorta, there is an increase in blood pressure—that is, the pressure of the blood upon the walls of the blood vessels. After the ventricle has started to relax, the pressure falls. The highest point in the pressure range is called the *systolic pressure*. The lowest point in the pressure is called the *diastolic pressure*. There is a gradual decrease in pressure as blood circulates from the arteries to the capillaries and from the capillaries to the veins. At the venae cavae, the two large veins that empty into the right auricle, the pressure is relatively slight.

To take a person's blood pressure, the physician generally measures the pressure in a large artery of the arm—the *brachial artery*. An instrument called a *sphygmomanometer* is used for this purpose. A cuff containing an airtight bag is wrapped around the upper arm. Two rubber tubes lead from the bag. One of them is connected to a rubber bulb. The other leads to a manometer, a **U**-shaped glass bulb containing mercury (Hg). One of the uprights of the **U** is fixed to a millimeter scale.

The physician inflates the cuff by pressing the bulb. Increasing pressure within the cuff causes the mercury to rise in the part of the manometer that is attached to the millimeter scale. The physician continues to pump air into the cuff until the pulse at the wrist disappears. This means that no blood is passing in the brachial artery below the cuff. He then applies a stethoscope to the artery just below the cuff. The air pressure in the cuff is reduced as the physician opens a valve on the tubing near the bulb. As soon as blood begins to move again in the artery below the cuff, a tapping sound is heard.

A reading is now taken. The physician notes the height of the mercury column in the glass tube. This reading represents the systolic pressure.

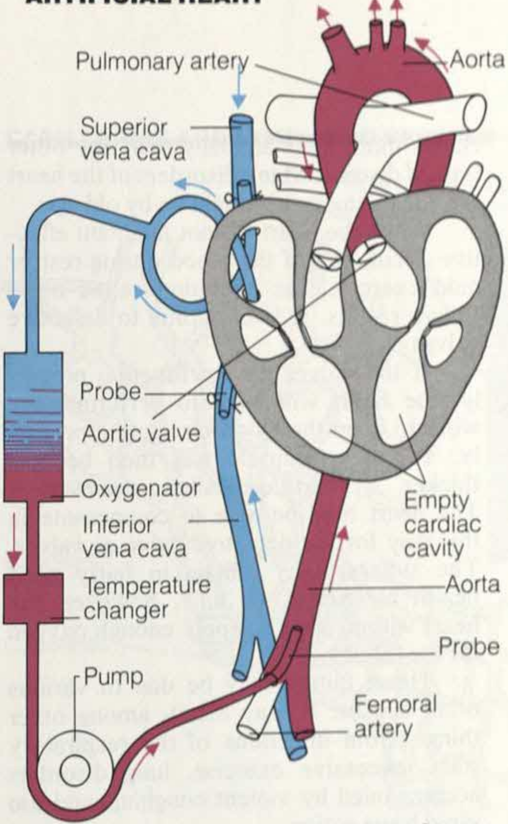
The physician releases more air from the cuff, and the pressure is lowered still more. The sound of the blood flowing through the artery becomes louder. Then it dwindles to a murmur and finally stops entirely. A reading is taken just before the sound disappears. This reading is the diastolic pressure.

In the young adult, the average systolic pressure is 120 mm. Hg. The average diastolic pressure is 80 mm. Hg. There are, however, pretty wide variations in blood pressure among healthy persons. Any systolic pressure over 140 or diastolic pressure over 100 is considered abnormal. This condition is called *hypertension,* or high blood pressure. In some persons, the blood pressure is lower than normal. Such persons are said to have low blood pressure, or *hypotension.*

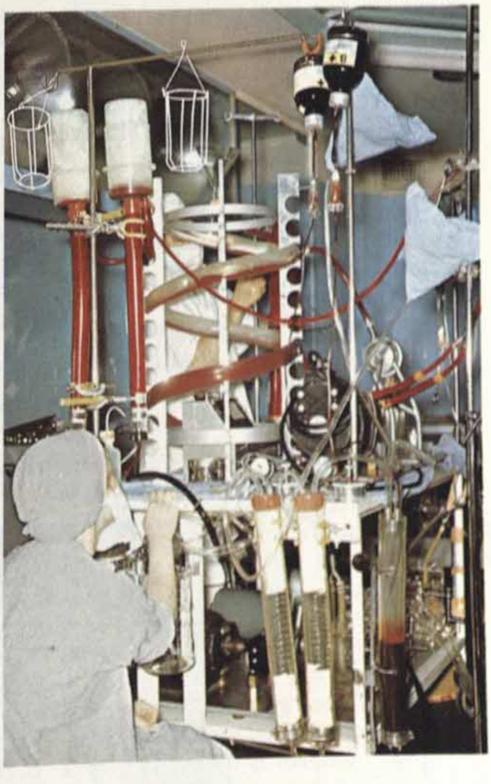
HEART DISORDERS

The heart is subject to a great many disorders. Disease affecting the heart

ARTIFICIAL HEART



Dorson – Fotogram



Researchers have developed various types of artificial hearts. During cardiac surgery, the blood is pumped through a mechanical device that oxygenates it.

claims more lives annually than any other type of disease. Many disorders of the heart are due to changes brought on by old age.

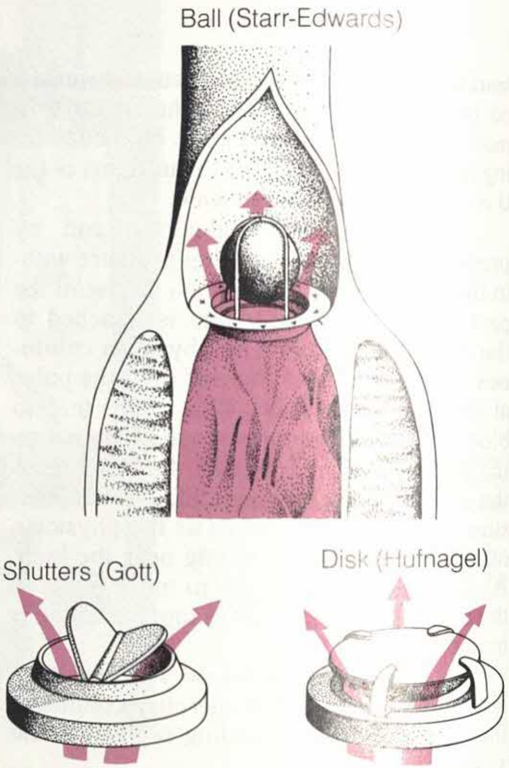
When the heart cannot maintain effective circulation of the blood during rest or mild exercise, the condition called *heart failure* results. It is often due to defective valves.

If the valves do not function properly, the heart will have to perform more work to keep the blood circulating properly. The heart muscle will then become thicker, a condition called *hypertrophy*. The heart may be able to compensate in this way for the defective valve or valves. The sufferer may remain in fairly good health for years. In time, however, the heart will no longer supply enough oxygen for the tissues.

Heart failure may be due to various other causes. It may result, among other things, from infections of the respiratory tract, excessive exercise, lung disorders accompanied by violent coughing, and too rapid heart action.

The first symptom of heart failure may be shortness of breath during mild exercise. Later, there is rapid pulse, swelling of the legs, especially around the ankles, coughing, and general weakness. The venous pressure rises. *Cyanosis* may develop—that is, the surface of the body may become blue because of the lack of oxygen. The liver and spleen may become enlarged.

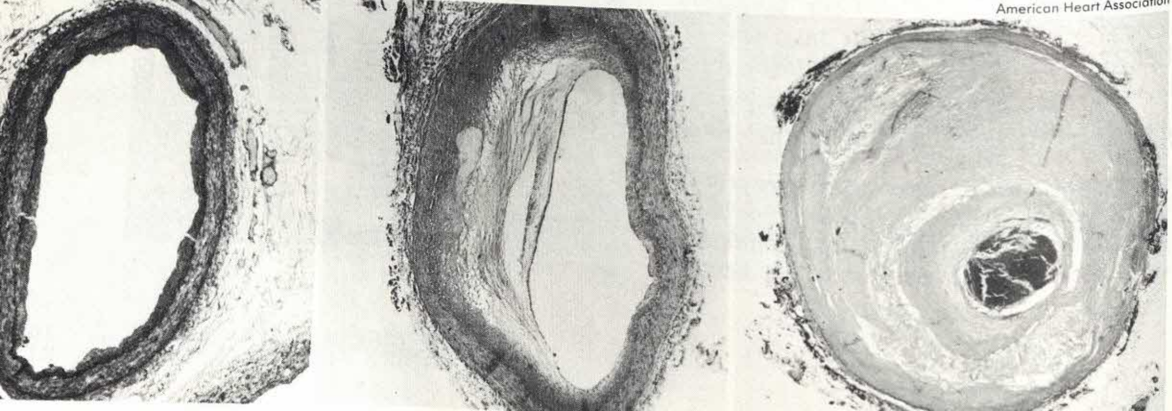
Various drugs are used to relieve sufferers. Among the most effective is digitalis. This drug stimulates the failing heart, improves the circulation, and relieves other symptoms of heart failure.


SOME ARTIFICIAL VALVES

Defective valves are a major cause of heart disease. Above, several types of artificial valves used in the treatment of some types of heart disease.

Coronary disease affects the coronary arteries, which supply the heart muscle with blood. These arteries may become clogged up. In this condition, called *atherosclerosis*, the middle layer of the artery degenerates. There is an overgrowth of fibers in the innermost layer, and calcium deposits form along the walls. The clogging up of the coronary arteries is a gradual process. Often, as one of these arteries is narrowed, new blood vessels develop in the tissues and help supply the heart.

The cross section of a healthy artery (left) is compared with an artery in which atherosclerotic deposits have formed on the lining (middle) and an artery that is nearly clogged with deposits (right).


American Heart Association

Sometimes the clogged-up arteries may close entirely as the result of a sudden spasm. This brings on *angina pectoris*, which means "pain in the chest," in Latin. Angina pectoris occurs in the region of the heart. Often it spreads to the left shoulder and down the left arm. Sometimes angina pectoris is caused by an insufficient supply of oxygen to the tissues. In such cases, the coronary arteries may be quite normal. Angina pectoris is relieved by various drugs, including amyl nitrite and nitroglycerine.

In the disease called *coronary thrombosis*, a blood clot forms in one part of the coronary arteries, shutting off part of the blood supply to the heart muscles. There is pain, which lasts much longer than the temporary pain of angina pectoris. Coronary thrombosis is often fatal. However a sufferer may survive several attacks.

In a *coronary embolism*, a blood vessel is suddenly plugged up by a blood clot that has broken loose from some other part of the body and that has been transported to the coronary arteries in the blood stream.

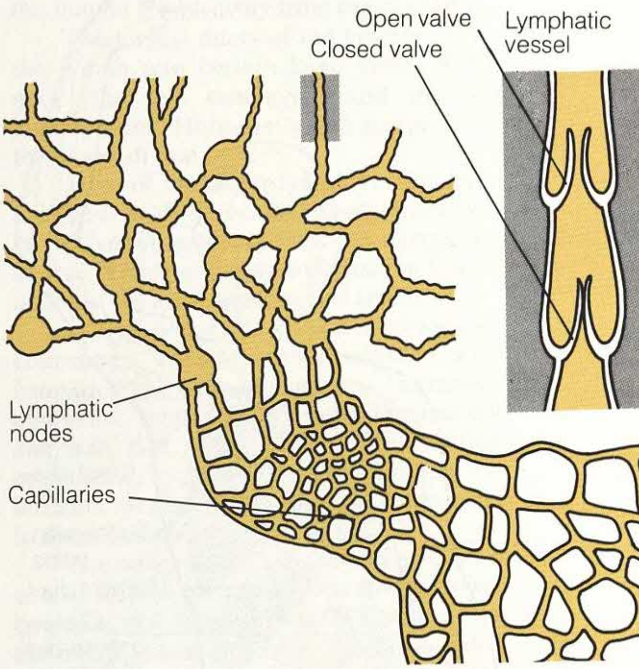
In the disorder called *auricular fibrillation*, the beat of the auricle is rapid and entirely irregular. Auricular fibrillation results from rheumatic fever and certain other diseases. It is relieved by the drug quinidine, which causes the heart muscle to lengthen the period between beats. Digitalis is also effective in treating this condition.

Some children are born with various defects of the heart. The pulmonary valve, between the right ventricle and the pulmonary artery, may be too small. There may be a hole between the wall separating the right and left auricles or the right and left ventricles, or there may be an abnormal connection between the pulmonary artery and the aorta. Some congenital conditions can often be corrected by surgery.

Blood circulation will be affected if the arteries or veins are attacked by disease. The aorta may become infected or, in a person who has had high blood pressure for many years, permanently dilated. If the walls of the aorta are weak, they may rupture.

The middle-sized arteries are particularly apt to be affected by arteriosclerosis. As we saw, this condition is particularly dangerous when it develops in the coronary arteries. Arteriosclerosis also attacks the smallest arteries, the arterioles. It cuts down the flow of blood and increases blood pressure.

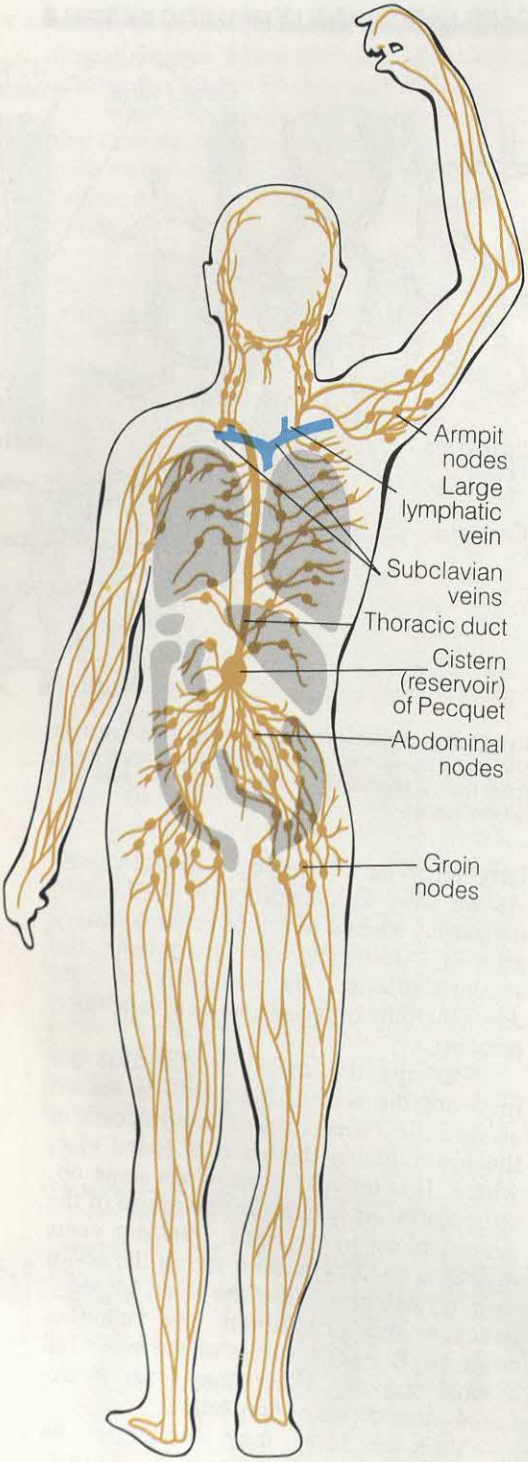
CAPILLARIES AND LYMPHATIC VESSELS



Lymphatic capillaries lead to larger lymph vessels that have valves that direct the flow of lymph away from the capillaries. The inset shows the valves in a lymph vessel.

Perhaps the most familiar disorder involving the veins is the condition known as *varicose veins*. It most often occurs in the lower limbs, though it is found elsewhere. It is brought about when some obstruction or other impedes the return of the venous blood to the heart. Varicose veins may be caused by tumors within the abdomen, by enlargement of the liver, by pregnancy, or other conditions. The veins become swollen. The valves of the veins fail to work properly. Ulcers may form. In extreme cases the veins may burst.

Varicose veins may sometimes be cured by removing the cause of the obstruction. Treatment often consists of rest in a



Lymph vessels carry lymph from the capillaries through the body until it joins the circulatory system, flowing into the subclavian and left jugular veins in the neck region.

horizontal position, bathing the affected limb in cold water. Sufferers from phlebitis may find relief by wearing a bandage, or a laced stocking, or a snugly fitting elastic stocking. In advanced cases it may be necessary to remove the obstructed portion of a vein.

Phlebitis, or inflammation of the veins, is a serious disorder. It may result from a wound or abscess outside of the vein. In certain cases the inflammation arises within the vein, because a clot has formed on the inner wall. Parts of the inflamed tissue may break off. They may be carried to other parts of the body by the blood circulation, causing similar inflammation elsewhere. The inflammation may cause a vein to be entirely stopped up. Death may result if a large vein is affected in this way. To treat this condition, medicines that counteract inflammation are prescribed. The patient is kept perfectly still, with the affected part raised. Abscesses within reach are opened. Fresh dressings are frequently applied to wounds.

Some persons with hypertension may lead quite normal lives. In other cases this condition has serious consequences. The high pressure of the blood against the walls of small arteries and capillaries may cause them to rupture. A break of this type in the brain is called a *cerebral hemorrhage,* or *stroke.* If a person who has extremely high blood pressure has a weak heart, the added work required of the heart may lead to a serious case of heart failure.

Among the symptoms of hypertension are general weakness, headache, shortness of breath, palpitation of the heart, and irritability. Hypertension may be a symptom of a disease, such as goiter or arteriosclerosis. In that case the disease must be treated to bring about relief. If high blood pressure is not connected with any other disorder, relaxation, sedatives, and salt-free diets are used in treatment. The diet recommendation is included since a high salt content diet is believed to play a role in hypertension.

Persons with hypotension generally tire quickly. In severe cases, the sufferer's digestion is affected. His hands and feet become cold. He is apt to feel dizzy when he gets up suddenly after lying down. In most cases persons with hypotension get along very well if they learn not to tax their strength.

Hemorrhage, or bleeding from arteries or veins, either within or outside of the body, is always dangerous. If more than 30 per cent or so of the blood volume is quickly lost, death will result unless blood transfusion takes place. If the amount of blood lost is not excessive, the body can generally repair the damage fairly rapidly.

It is usually easy to tell whether the blood comes from an artery, vein, or capillary. If it is from an artery, it escapes in spurts and is bright scarlet in color. Blood from a vein is darker and flows more slowly. It wells up at the site of a wound. If the blood is from capillaries, it oozes slowly and quickly clots.

LYMPHATIC SYSTEM

The so-called lymphatic system, found in all parts of the body, is intimately connected with the blood circulation. The *lymphatic system* is made up of a series of ducts – the *lymph vessels* – and it carries a fluid called *lymph.*

Lymph resembles blood plasma, the liquid part of the blood. Its protein content, however, is much lower. Lymph is derived from the tissue fluid that occupies the space between cells in body tissues. Not all of this fluid enters the lymph system. Some of it passes into the capillary network of the blood circulation and is carried along in the veins until it reaches the heart. It is transported, therefore, in the regular venous system.

The lymphatic system begins in the *lymphatic capillaries,* through which tissue fluid passes. These ducts differ in several respects from the ordinary capillaries of the circulatory system. Lymphatic capillaries are not connected, of course, to a system of ordinary capillaries. The lymphatic capillaries lead to larger lymph vessels. These larger lymph vessels have valves that direct the flow of lymph away from the capillaries.

The largest ducts of the system empty the lymph into certain large veins of the neck – the left subclavian and the left jugular veins. Here the lymph merges with the blood stream.

Most of the larger lymph vessels have enlarged oval- or bean-shaped structures, called *lymph nodes,* at intervals along their course. These are concentrations of lymph nodes in the neck, armpits and groin.

Lymph nodes consist of a meshwork of connective tissue, packed tightly with *lymphocytes* and *phagocytes.* Lymphocytes are white blood cells. Phagocytes are cells that attack and engulf invading organisms. Lymph must pass through the intricate meshes of the nodes as it proceeds to the subclavian veins.

The nodes act as effective filters. They entrap various particles of matter, including bacteria, and therefore remove them from the blood stream. Bacteria caught and held in the meshes are destroyed in great numbers by the phagocytic cells. The lymph nodes, therefore, represent an important line of defense against germs that have peretrated the blood stream. Lymph nodes manufacture great numbers of lymphocytes. These cells are responsible for the production of antibodies, which help protect the body against disease.

Of course, since germs are enmeshed in the lymph nodes, they will collect there in great numbers in the event of a serious infection. The phagocytic cells may not be able to dispose of them effectively enough. The result may be a local infection at the nodes. For example, if the throat is infected, the lymph nodes of the neck may swell and become tender. The doctor, therefore, examines the nodes in such cases to find out how severe the infection is and how widely it has spread.

The lymph system plays an important part in the spread of cancer throughout the body, carrying cancerous tissue from a malignant growth to a different spot in the body. For this reason lymph nodes near a cancerous growth are often removed when cancer surgery is performed.

THE RESPIRATORY SYSTEM

Oxygen is necessary for all body functions. Cells obtain most of their energy from chemical reactions involving oxygen. These chemical reactions are the burning of the fuels we call food.

In lower animals, such as the ameba, oxygen simply diffuses through the cell membranes. In higher animals that have a complex multicellular organization, this is not possible. Instead, higher animals have particular structures specialized to capture oxygen. In humans and many other higher animals, these specialized organs are called *lungs*. The lungs take in oxygen from the air. Some other animals have different organs – gills – that take oxygen from water.

The process by which the lungs take in oxygen is *respiration,* or breathing. In humans, several other organs besides the lungs also function in respiration. These organs make up the *respiratory system*. The respiratory system also functions to rid the body of waste products – mainly carbon dioxide.

The process of taking in air into the body is called *inspiration,* or *inhaling*. Releasing air and accumulated carbon dioxide from the body is called *expiration,* or *exhaling*.

The major parts of the respiratory system are the nose, the trachea, the bronchial tubes, and the lungs.

AIR ENTERS THE SYSTEM

Air is inhaled through the nose or the mouth.

Nose. Numerous hairs at the entrance to the nostrils keep out some of the particles of dirt or other foreign matter that otherwise would be inhaled. Other particles are kept from the lungs by tiny hairlike structures, called *cilia,* which cover the mucous membrane of the nose. These cilia suggest a rippling field of wheat in a mild breeze. They move in waves, much as the stems of wheat plants move when a breeze strikes them. As they undulate, the cilia whip particles of foreign matter toward the pharynx, where we can get rid of them by clearing the throat.

The mucous membrane of the nose is always moist and gives up some of its moisture to the air that is inhaled. Therefore this air is moistened and also warmed before it enters the lungs.

Mouth. When we breathe through the mouth, we inhale some of the particles of foreign matter that would have been eliminated in nose breathing. In addition, the air is not sufficiently warmed before it enters the lungs. There are times, it is true, when mouth breathing is necessary, as when the nasal passages are closed because of inflammation of the mucous membrane. But under normal conditions, air should be drawn in not through the mouth but through the nostrils.

Pharynx and larynx. After it has gone through the nose, the air passes freely through the *pharynx* and then through the *larynx*, in which the vocal cords are located. Just before entering the larynx, it crosses the path of food and drink to the *esophagus*.

If food particles bound for the esophagus penetrated into the larynx, the results would be serious. Fortunately, this rarely happens. As we swallow, all the possible pathways for food, other than the esophagus, are closed off by muscular contractions. Of course, if we inhaled at the very same time that we swallowed food, certain food particles would almost certainly be forced into the lungs. But the swallowing mechanism is so geared with the breathing mechanism that this is almost impossible. The sensory nerves that bring about the swallowing movements send impulses at the same time to the respiratory nerve center, preventing inhalation. Another safeguard is also provided. With each swallowing movement, the larynx is lifted upward. This brings it under the base of the tongue. A structure called the *epiglottis* is then pressed against the opening to the larynx, forming a sort of closed lid.

Once in a while, it is true, a food particle will go down the wrong way and will make its way into the air passages. It may partially or totally obstruct breathing. If a person begins to choke on food, a simple technique taught in first-aid courses will dislodge the food from the air way. Rarely are surgical procedures necessary. If food somehow entered the lungs, it may cause serious infection, since it is probably contaminated with bacteria.

The position of the larynx at the very entrance to the windpipe and the narrow gap between the vocal cords is an adaptation for speech. It has nothing to do with the normal process of breathing. Of course, breathing is exceedingly important in the production of sound, since the passing of air through the larynx causes the vocal cords to vibrate.

AIR PASSES INTO THE LUNGS

Air passes through the pharynx into the trachea and from there into the bronchi and the lungs.

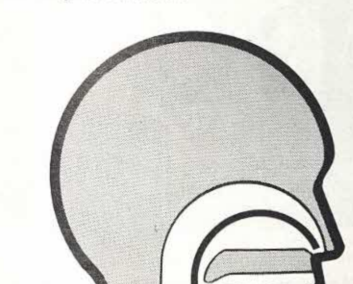
Trachea. The windpipe, or trachea, is a tube about ten centimeters long, on the average. It lies partly in the neck and partly in the chest cavity, or thorax. Unlike the esophagus, whose walls are in constant contact except when food is passing down, the trachea is kept open at all times. For this purpose, its walls are stiffened by rings of cartilage. We can easily feel some of these rings in the neck, just below the larynx. The tube is lined internally with tissue containing great numbers of cilia. These whip upward any fluids or foreign particles that have entered the trachea, particularly as a result of mouth breathing.

Bronchi. The trachea branches off into two tubes, called *bronchi,* running to the lower back part of each lung. There is a left and a right bronchus, corresponding to the left and right lung, respectively.

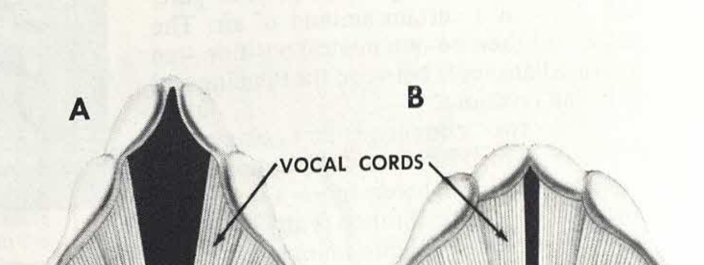
Lung. In the lung, the bronchi divide into smaller tubes, called *bronchial rami.* The rami branch off into still smaller tubes, known as *bronchioles.* Finally, the bronchioles end in clusters of air sacs – the *alveoli.* These sacs have exceptionally thin walls, consisting of a single layer of cells. The alveoli always contain a certain amount of air.

In addition to the bronchial tubes and the alveoli, the lungs contain a great many blood vessels – arteries, veins, and capillaries. The arteries carry blood away from the heart, while the veins carry blood to the heart. The capillaries form a network between the arteries and the veins. The capillaries of the lungs surround the alveoli.

Below: the pathways of food and air cross each other in the human body. To indicate the passages more clearly, the drawing has been distorted and the larynx omitted.



Two views of the vocal cords, which stretch across the cavity of the larynx. In ordinary breathing, there is a fairly wide space, triangular in shape, between the cords *(A).* Whenever we speak, sing, or make a noise, the cords are adducted, or drawn together, as in *B.* They vibrate to produce the sound. In high-pitched sounds, the space between them becomes a narrow slit.



Their walls, like those of the alveoli, consist of a single layer of cells.

There is a great deal of connective tissue in the lung, giving these organs an elastic quality that, as we shall see, plays an important part in breathing. The lungs are also provided with an extensive and complex nerve system.

MECHANICS OF BREATHING

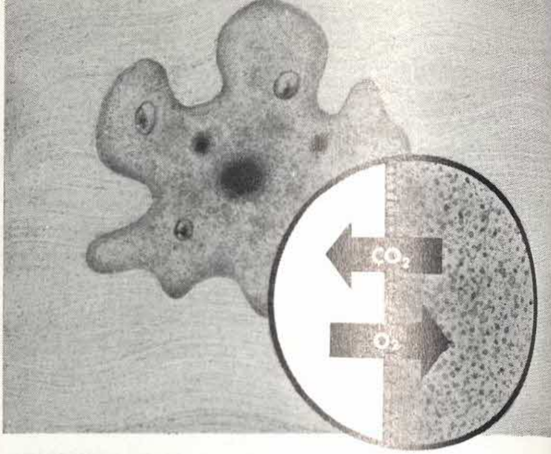
The breathing apparatus consists not only of the air passages and the lungs but of various muscles in the body. To understand the mechanics of breathing, we should remember that the lungs are enclosed within the chest cavity. The sides and dome of this cavity are formed by the chest wall, which is strengthened by the ribs. Below, the chest cavity is bounded by a large dome-shaped muscle known as the *diaphragm*. It is attached at the back to the lower ribs and backbone and in front of the breastbone.

Drawing air into the lungs may be compared to sucking air into a pair of bellows by pulling the two handles of the device apart. When the diaphragm is pulled downward toward the abdomen and when the ribs are pulled upward and outward, the volume of the chest cavity is increased. Air is then drawn into the lungs through the force of atmospheric pressure, and they become fully distended. In expiration, the muscles that brought about inspiration relax and the diaphragm rises to its former position. The natural elasticity of the lung tissue then causes the lungs to contract, expelling air. As soon as you have exhaled, the lungs, without any effort on your part, will draw in a certain amount of air. The chest will then be in a neutral position – an intermediate stage between the inhaling and exhaling positions.

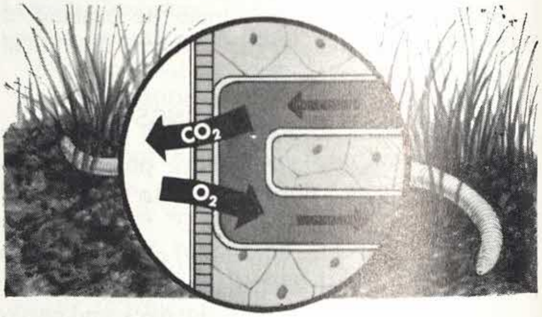
The two complementary phases of breathing – inspiration and expiration – are repeated about eighteen times a minute as long as we live. Respiration is an essentially automatic process. It continues even during the deepest sleep.

ARTIFICIAL RESPIRATION

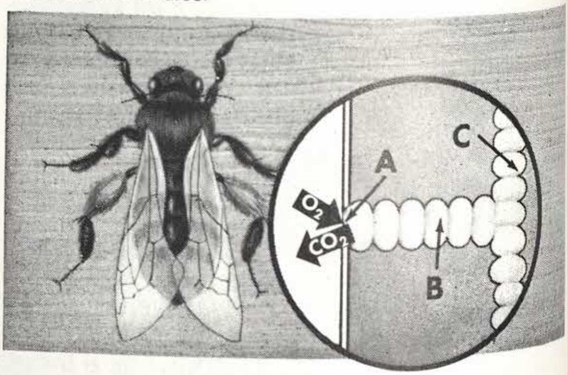
When breathing stops, life can be sustained by *artificial respiration*, which may



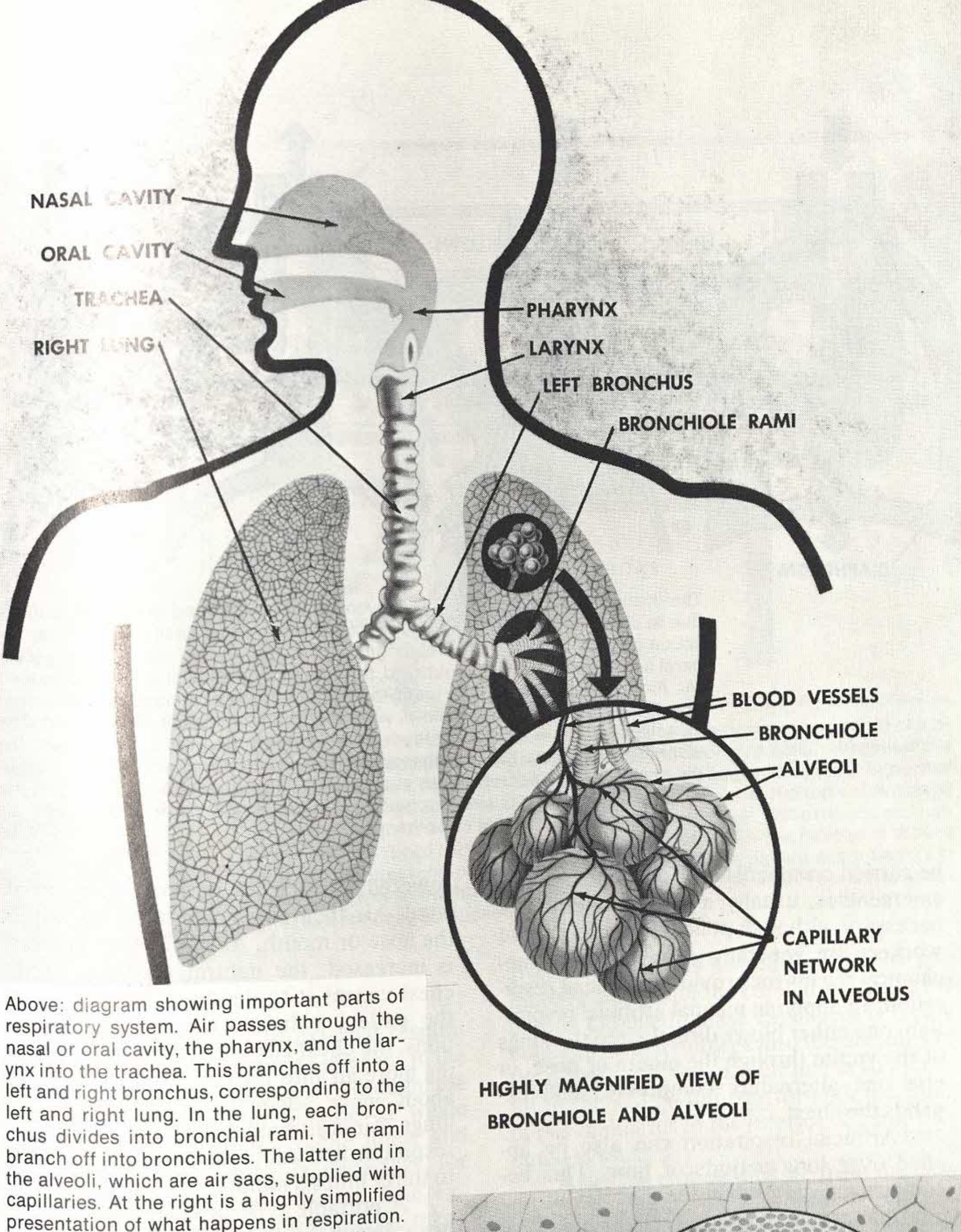
In respiration, or breathing, oxygen is taken into the cell or cells, combustion takes place, and carbon dioxide is expelled. The one-celled ameba, above, breathes through the entire surface of its body. Oxygen enters the cell and carbon dioxide passes out of it.



The earthworm (above) is far more highly developed than the ameba. Yet in this animal, too, the whole surface of the body takes part in breathing. To ensure the absorption of air by the blood, the respiratory surface must be moist. If the worm is exposed to sunlight, the skin becomes hardened, and the animal dies.

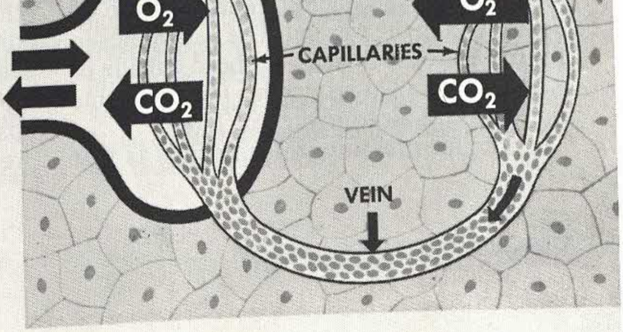


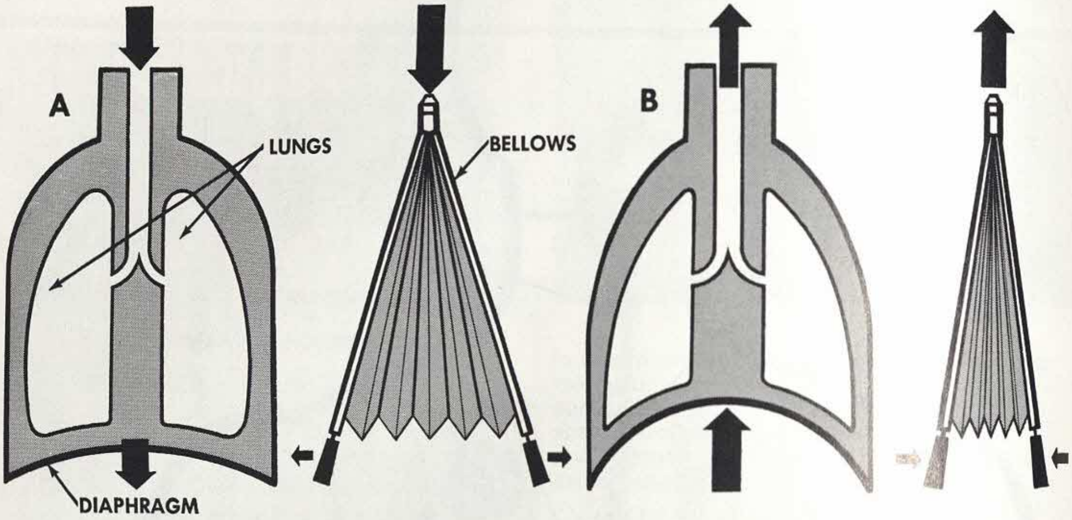
The breathing mechanism of insects is more effective than that of earthworms. Air enters through openings called spiracles *(A)* into a series of tubes – the tracheae *(B)*. From there the air goes into the main tubes *(C)* running along the body. Various branches lead from these vessels to every part of the insect's body.



Above: diagram showing important parts of respiratory system. Air passes through the nasal or oral cavity, the pharynx, and the larynx into the trachea. This branches off into a left and right bronchus, corresponding to the left and right lung. In the lung, each bronchus divides into bronchial rami. The rami branch off into bronchioles. The latter end in the alveoli, which are air sacs, supplied with capillaries. At the right is a highly simplified presentation of what happens in respiration. Oxygen contained in inhaled air diffuses through the walls of the capillaries in the lungs and passes into the blood stream. It is carried to the arteries and from the arteries to capillaries in all parts of the body. Diffusing through the capillary walls, it passes through the tissue fluid and from there to the body cells. Carbon dioxide (CO_2) passes from the cells to the tissue fluid and from there to the capillaries. It is then carried in the blood stream to the veins and ultimately makes its way to capillaries in the lungs. Diffusing out of the capillaries, much of it is expelled from the lungs when we exhale.

HIGHLY MAGNIFIED VIEW OF BRONCHIOLE AND ALVEOLI





The mechanics of breathing. The movement of air into and out of the lungs is due to alternate expansion and contraction of the chest cavity, suggesting the action of bellows. When the diaphragm is pulled down and the ribs (not shown here) are drawn upward and outward, the volume of the chest cavity is increased *(A)*. Air is then drawn into the lungs through the force of atmospheric pressure, just as it is sucked into the bellows whenever the handles are moved apart. The muscles that caused the diaphragm to be lowered then relax. As a result, the diaphragm rises and the rib cage moves inward and downward. The volume of the chest cavity is decreased, as shown in *B*. This corresponds to bringing the handles of the bellows closer together. The lungs now contract and expel air containing carbon dioxide and other wastes.

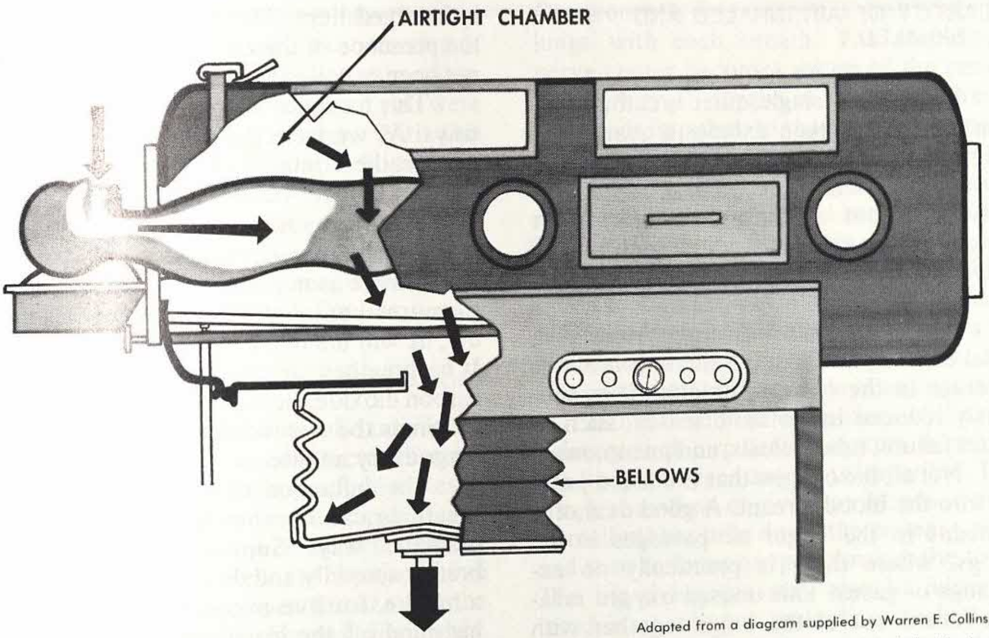
be carried on manually or mechanically. In emergencies, usually a manual method is necessary, although police, fire, and rescue workers are generally equipped with mechanical means for providing artificial respiration. In applying manual artificial respiration, one either blows directly into the lungs of the victim through the mouth or nose, or else one alternately compresses and expands the chest.

Artificial respiration can also be applied over long periods of time. This becomes necessary when the muscles of respiration are paralyzed. One of the best known of the long-range respiration devices is the Emerson respirator, which is also known as the iron lung. It consists of a metal cabinet, to which is attached a pump that changes the quantity and pressure of the air within the cabinet. The patient lies in the respirator, with only his head outside of it. A rubber collar around his neck prevents the escape of air from the iron lung.

The air pressure in the cabinet is first lowered, causing the patient's chest to expand. Air then enters the lungs by way of the nose or mouth. As cabinet air-pressure is increased, the natural elasticity of the chest causes it to decrease in volume, and the patient exhales. Under some conditions, the chest can be compressed by forcing more air into the cabinet, thus bringing about more adequate ventilation of the lungs. Air is alternately withdrawn from the respirator and admitted into it from fifteen to thirty times a minute.

A portable type of respirator has also been developed. This device has no cabinet. It consists of a dome-shaped breastplate, which is attached to the chest and connected to a pump.

Usually, there is some improvement in the muscles used in respiration after the disease has run its course, and the patient can often dispense entirely with the respirator. In certain extreme cases, however, the patient must rely on this type of artificial respiration as long as he lives.



Adapted from a diagram supplied by Warren E. Collins, Inc.

How the iron lung works. The body of the patient is enclosed in an airtight chamber with the head outside and sealed around the neck by a collar. Whenever the bellows is moved down, the air pressure in the chamber (originally at normal atmospheric level) is lowered. The air around the head of the patient is now at greater pressure relative to the pressure in the chamber. Atmospheric air then flows into the lungs by way of the nose or mouth. When the bellows is moved upward, the pressure in the iron lung is increased. The patient accordingly exhales passively through the muscular recoil of his chest wall. Pressure to assist in exhalation may be applied.

GAS IN THE LUNGS

The essential part of external respiration consists of the exchange of gases in the lungs. The blood that passes through the lungs gives up carbon dioxide – a waste product of combustion – to the lungs and receives oxygen, which is necessary for combustion in the body tissues. The exchange of oxygen and carbon dioxide takes place between the alveoli and the capillaries by the process of diffusion.

In this process, molecules tend to pass from an area where they are highly concentrated to an area where the concentration is not so high. As they diffuse in this way, the molecules of oxygen or carbon dioxide pass freely through the walls of the capillaries and the alveoli, which, as we saw, are exceedingly thin.

The blood that has come to the heart from the veins has passed through the pulmonary artery into the capillaries. Since the carbon dioxide in these capillaries is highly concentrated, it diffuses into the alveoli. On the other hand, the oxygen that is so plentiful in the alveoli diffuses through the walls of the capillaries to the interior of these tiny blood vessels.

After the carbon dioxide from the capillaries has made its way into the alveoli, much of it is withdrawn from the lungs as we exhale. When the diffused oxygen has passed into the capillaries, it unites with the hemoglobin of the red blood cells. This hemoglobin becomes the oxygen-carrying factor. The blood, now enriched with a fresh supply of oxygen, passes through the pulmonary veins into the left auricle of the heart and from there into the left ventricle. It is then pumped through the arteries to the tissues of the body.

QUANTITY OF AIR INHALED AND EXHALED

With every single quiet breath, a person inhales and then exhales a quantity of air measuring about 500 cubic centimeters. If you breathe in as deeply as possible and then blow out as hard as you can, the amount of air exhaled is known as the *vital capacity*. This is measured by means of a sort of tank, called a *spirometer*. For a man of average size and in average health, the vital capacity is about 3.5 liters. It is above average in the case of athletes. It is seriously reduced in certain diseases, such as heart failure, tuberculosis, and pneumonia.

Not all the oxygen that is inhaled passes into the blood stream. A good deal of it remains in the larger air passages in the lungs, where there is practically no exchange of gases. This unused oxygen is later forced out of the lungs together with carbon dioxide.

CARBON DIOXIDE STIMULATES BREATHING

Of the carbon dioxide carried in the blood, a certain amount is not exhaled but remains behind in the bronchial tubes. At the beginning of the next breath, some of this carbon dioxide will be drawn into the lungs, together with oxygen derived from the outer air. This is not so great a calamity as it might appear to be.

It is true that carbon dioxide is the chief waste product carried in the blood stream. If it is allowed to accumulate indefinitely, death will result, because carbon dioxide prevents combustion from taking place.

In the human body, carbon dioxide is dangerous only when the excess of this gas is not removed. As a matter of fact, the presence of the gas has a stimulating effect upon respiration. It is the chief factor in keeping up a constant cycle of breathing. For example, if certain nerves that control the automatic part of breathing are cut, respiration becomes somewhat slower and deeper, but it will continue to be automatic and it will suffice to maintain life. Obviously, something else besides nerve responses is involved here. That "something else" is the presence of the carbon dioxide that has not been expelled from the lungs.

This has been demonstrated in several ways. As we have pointed out, the air that we breathe contains only a slight trace of carbon dioxide—about 0.03 per cent. But suppose a person is made to breathe air containing 3 per cent of this gas. He will inhale twice as much air as usual. Instead of the normal amount of eight liters per minute, he will inhale sixteen liters per minute. If he breathes air containing 6 per cent of carbon dioxide, he will draw something like six times the normal volume of air into his lungs every minute.

The influence of carbon dioxide on breathing can be shown in an even more dramatic way. Suppose that a person breathes rapidly and deeply, say forty times a minute, for five minutes, and then takes his mind off the breathing process for the next few minutes. An observer will note that the subject will stop breathing for two minutes or thereabouts. He may become rather blue in the face before he resumes the breathing process. He will probably gulp in the air spasmodically before the normal respiratory rhythm is restored. Sometimes he will not resume breathing and will collapse. What has happened? By his forced breathing, the subject has removed so much carbon dioxide from his body that very little of it is left to stimulate respiration. The excessive breathing that brings on this condition is called *hyperventilation.*

Apparently carbon dioxide affects breathing by acting upon the *respiratory nerve center*. As carbon dioxide accumulates in this nerve center as well as in the other parts of the body, it will stimulate the center to action and will result in movements of the muscles that control the mechanical act of breathing.

OTHER BREATHING STIMULI

There are various other stimuli to respiration. Impulses arising in the skin apparently have a definite effect upon the breathing process. Such impulses account for the first breath that a baby draws when it is born. Usually, as soon as the infant emerges from the mother's body, the stimulus of the cold outer air upon its naked skin makes it gasp much as you would gasp it you were plunged under a cold shower. With this gasp the breathing cycle starts. Sometimes the doctor applies another type of stimulus to the skin if breathing does not take place as a result of the baby's contact with the outer air. He spanks the infant a few times, and often breathing will follow as a consequence.

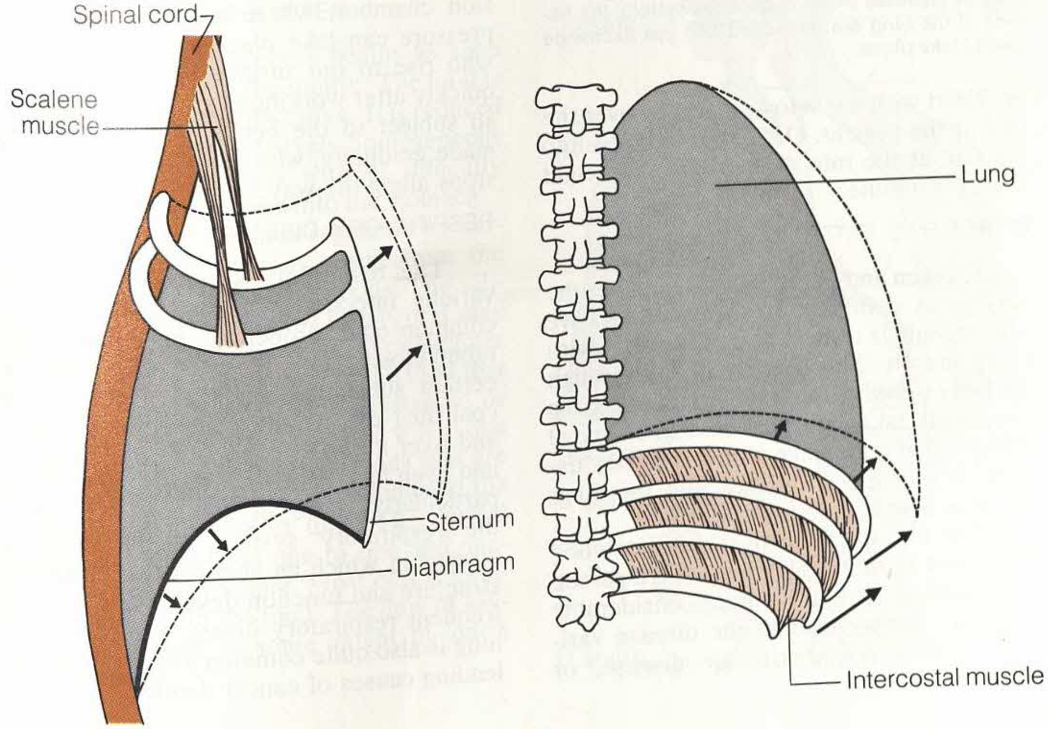
OXYGEN DEFICIENCY AND RESPIRATION

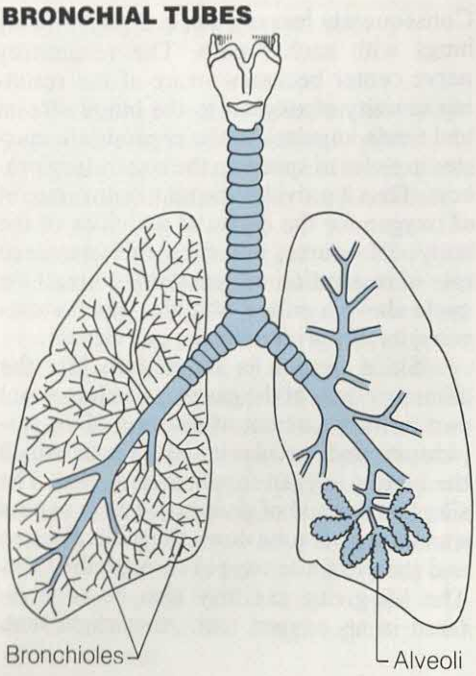
The quantity of carbon dioxide in the blood stream is not the only factor that will alter the breathing rate appreciably. Respiration also becomes more rapid if the amount of oxygen in the blood is noticeably diminished. For example, as we rise above sea level, the air becomes thinner and the number of oxygen molecules diminishes. Consequently less oxygen is drawn into the lungs with each breath. The respiratory nerve center becomes aware of the resulting scarcity of oxygen in the blood stream and sends impulses to the appropriate muscles in order to speed up the respiratory process. Thus it provides the maximum amount of oxygen for the essential activities of the body. Of course, not even this increased rate of respiration will sustain the breathing cycle above a critical altitude, which varies considerably with different individuals.

Since oxygen is so vital to life, the administration of the gas plays an important part in the treatment of diseases of the respiratory and circulatory system in which the body's oxygen supply is imperiled. The simplest method of giving oxygen is to pass a small rubber tube down the patient's nose and then to force oxygen through the tube. The life-giving gas may also be administered in an oxygen tent. An airtight tent,

The volume of the thoracic cage changes as we breathe. As air is drawn into the lungs, they expand, enlarging the chest cavity. The diaphragm is pulled downward and the ribs are pulled outward and upward.

DIFFERENCE IN THE VOLUME OF THE RIB CAGE WHILE INHALING





Gas exchange in the lungs takes place across the capillaries and alveoli. Oxygen passes from the alveoli to the capillaries, which then, through the circulatory system, supply all the tissues of the body with oxygen. Carbon dioxide passes from the capillaries to the alveoli, from which most of it is exhaled. In some diseases of the respiratory system, the tissues of the lung are destroyed and gas exchange cannot take place.

provided with a window, is placed over the bed of the patient. Oxygen is bubbled into the tent at the rate of approximately eight liters per minute.

NITROGEN'S FATE

Oxygen and carbon dioxide are not the only gases contained in the blood. As we saw, we inhale a good deal of nitrogen with every breath. This gas circulates through the body dissolved in the blood. Unlike the oxygen, it takes no part in the chemical changes that take place within the body tissues. Ultimately it diffuses into the lungs and is exhaled.

The dissolved nitrogen in the blood may cause a great deal of trouble if a person has breathed air that is under considerable pressure. It may lead to the disease variously called compressed-air disease, or decompression sickness, or caisson disease, or the bends. In a pneumatic caisson, which is used in underwater work, the air is pumped in under pressure to prevent water from penetrating. A worker breathing this air feels nothing unusual, except that he cannot whisper or whistle. There is pain occasionally if the Eustachian tube is not open. The Eustachian tube connects the middle ear with the upper part of the pharynx. Under such conditions of increased pressure, the blood will take up much more nitrogen from the lungs than it would under ordinary conditions.

If the worker is returned too speedily to normal pressure at the end of the day's work, he may fall victim to the "bends. The reduced pressure will cause bubbles of nitrogen to form in the blood. The blood will literally fizz like the contents of a bottle of soda water when the stopper is removed. These bubbles often become lodged in the bone joints, causing pain, crippling, or paralysis. Sometimes the nitrogen bubbles may plug various blood vessels in the lungs, brain, and heart. The consequences of caisson disease are serious or fatal unless the afflicted person is rushed to a decompression chamber, where the lowering of air pressure can take place gradually. Divers who rise to the surface of the water too quickly after working at great depths are also subject to the bends, so the ascent is made gradually, with many decompression stops along the way.

RESPIRATORY DISEASES

The respiratory system is subject to various infectious diseases including the common cold, bronchitis, pneumonia, and tuberculosis. The repeated inhalation of certain substances such as asbestos and coal dust can irritate respiratory passages and over a period of time produce serious and even fatal diseases. Allergy symptoms, particularly those of asthma, also affect the respiratory system. Emphysema, a disease in which an abnormality of alveoli structure and function develops, is another frequent respiratory illness. Cancer of the lung is also quite common and is one of the leading causes of cancer deaths.

THE DIGESTIVE SYSTEM

by Smith Freeman

The human body requires a constant supply of food in order to carry on its numerous activities. All foods have to be made soluble and some of them must undergo certain drastic chemical changes before they can be absorbed and assimilated in the tissues of the body. These all-important transformations take place in the *digestive tract*, or *alimentary canal.*

The digestive tract consists of a long tube that runs through the body and is expanded in certain places. It is made up of the mouth, the pharynx (the back part of the mouth), the esophagus (a tube connecting the mouth with the stomach), the stomach, the small and large intestines, the rectum, and the anus. Certain glands—the salivary glands, the liver, and the pancreas—are situated outside of the alimentary canal, but pour their secretions into it through ducts. The stomach and the large and small intestines form what is called the *gastrointestinal tract.*

FOOD ENTERS THE SYSTEM

The digestive process begins as soon as food is taken into the mouth. The food is chewed and mixed with saliva. It is reduced to a bland and comparatively homogeneous mass, which can pass without difficulty down the esophagus and into the stomach.

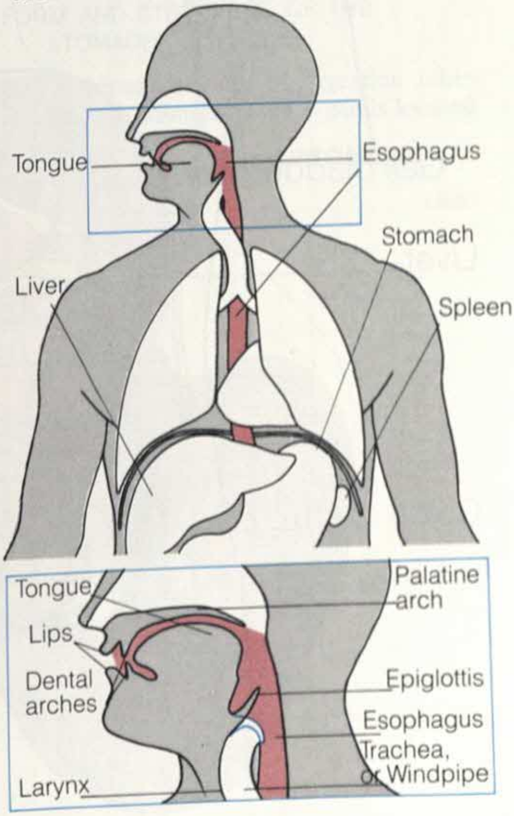
The flow of saliva is regulated by nervous stimuli, which may result from the sight or smell of appetizing foods. The saliva may be watery and flow freely, or it may be relatively scant and thick. Its character is determined by the nature of the food that is eaten. For example, sour substances or those that require much chewing will evoke a greater flow of saliva than foods that are bland and moist and that are retained in the mouth for a very short time. The normal person secretes from one to one and one-half liters of saliva daily. Most of it is swallowed along with the food. The flow of saliva is influenced to some extent by one's temperament.

Saliva contains a substance called *ptyalin.* While food is still in the mouth, this substance acts upon the starches that are present. It tends to break down the complex molecules of starches into simpler ones. The effect of ptyalin may continue inside a ball of food for some time after the food reaches the stomach.

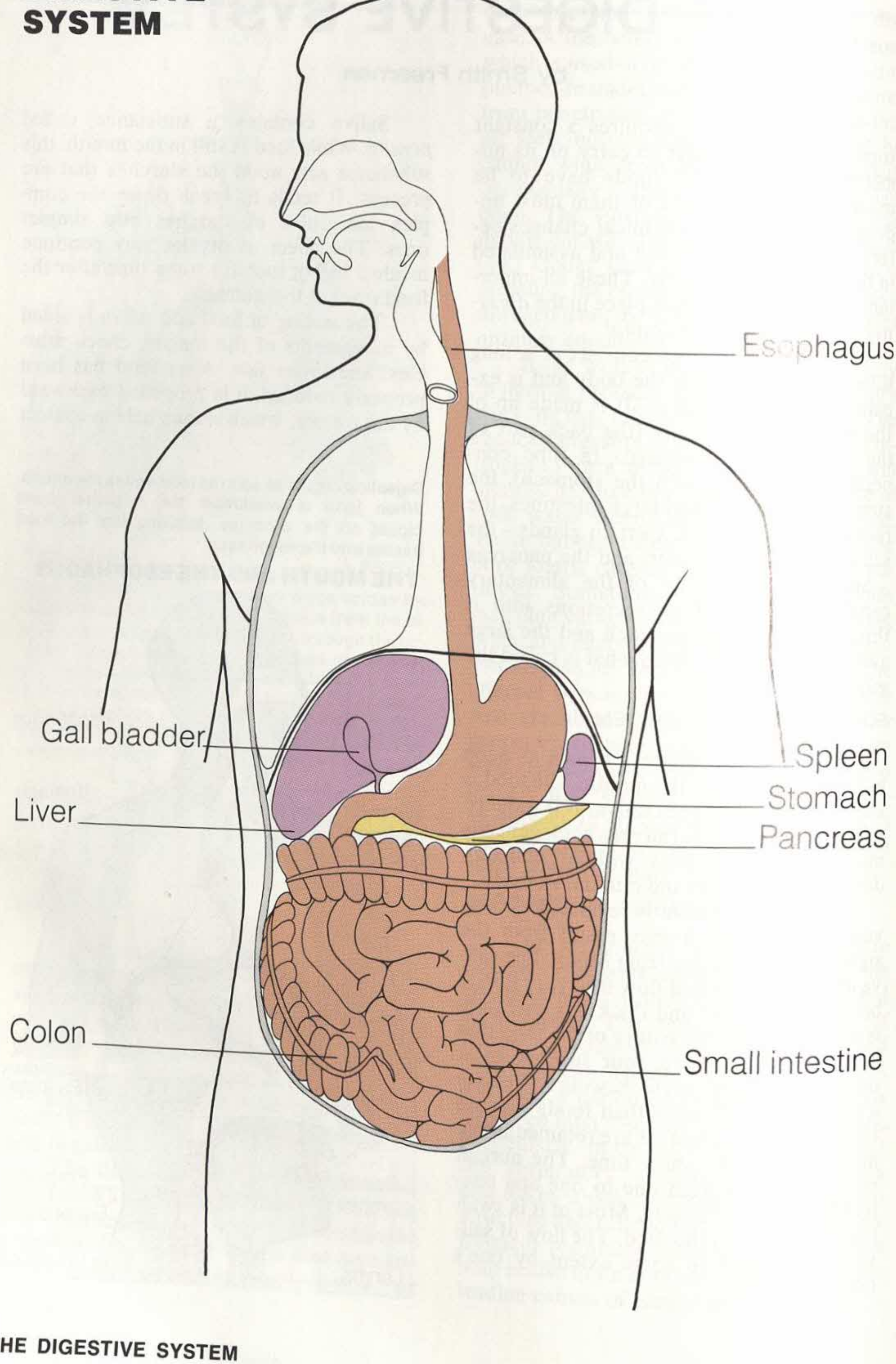
The mixing of food and saliva is aided by movements of the tongue, cheek muscles, and lower jaw. After food has been properly reduced, it is propelled backward by the tongue, which is then held in contact

Digestion begins as soon as food enters the mouth. When food is swallowed, the epiglottis (blue) closes off the windpipe, assuring that the food passes into the esophagus.

THE MOUTH AND THE ESOPHAGUS



DIGESTIVE SYSTEM



with the roof of the mouth. At the same time the soft palate closes off the nasopharynx, the upper part of the pharynx, continuous with the nasal passages, so that food cannot enter the nose. The base of the tongue and epiglottis help to protect the opening into the larynx, which is elevated and closed.

The muscles in the back of the mouth first relax to receive the *bolus,* or ball, of food. Then the constrictor muscles of the pharynx contract and the food is forced into the only available opening—the upper end of the esophagus, whose muscles are relaxed.

ESOPHAGUS

The esophagus is a thick-walled tube, whose inner surface is lined with mucous membrane. The wave of contraction in the esophagus continues just above the ball of food. The portion of the esophagus just below it relaxes. In this way food is carried through the esophagus to the entrance of the stomach. A ring of muscle, called the *cardiac sphincter,* is generally drawn tight around this opening. Now, however, it relaxes and permits the ball of food to pass into the stomach. The cardiac sphincter is the first of a series of ringlike sphincters that are found in the alimentary canal.

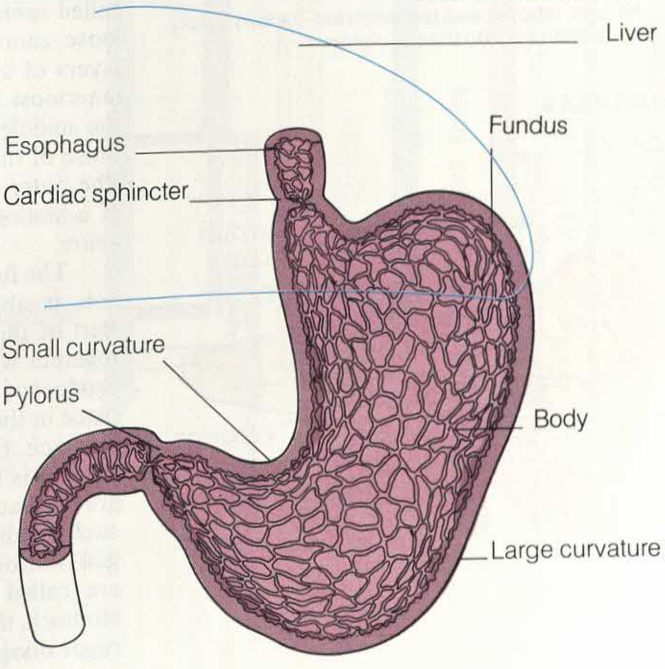
The same procedure takes place after each swallow of food. If the bolus is unusually dry or too large and becomes lodged in the esophagus, secondary waves of contraction will arise at the obstruction site. The mechanism involved in rapid swallowing, as when one drinks without pause, is different. In rapid swallowing, the entire length of the esophagus will relax and remain this way until the very last swallow.

Only the first part of the act of swallowing is under voluntary control. The rest of the swallowing process takes place independently of our will. That is true also of the various processes of digestion and absorption that follow. It is not until we deliberately relax certain muscles of the anus in the act of defecation, or elimination of wastes from the body, that we again control the action of the alimentary canal.

FORM AND STRUCTURE OF THE STOMACH

A certain amount of digestion takes place in the stomach. This organ is located

THE STOMACH



The human stomach is usually J-shaped. Its inner lining contains folds, or rugae, which increase the surface area of the stomach.

in the upper left part of the abdominal cavity. In most people it is shaped somewhat like the capital letter J. In some, however, it looks like a reversed capital L and in others like a cow's horn.

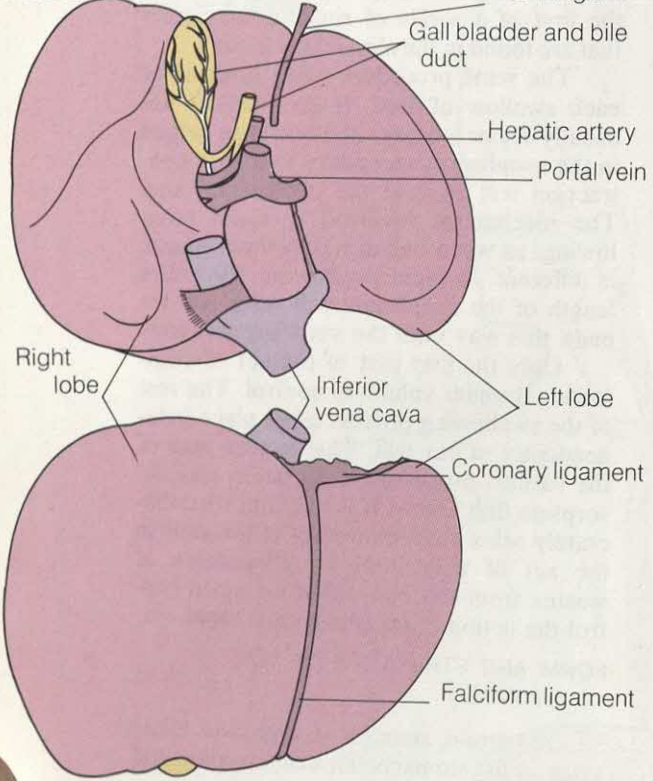
The part of the stomach lying above the opening from the esophagus is called the *fundus*. The part below the fundus and extending to the hook of the J, in J-shaped stomachs, is known as the *body*. The name *pylorus* is given to the rest of the organ. The average capacity of an adult's empty stomach is approximately one liter.

The position of the stomach in the body appears to have no particular significance as far as its functioning is concerned. The position varies in different individuals. In some people, the stomach lies lengthwise across the upper part of the abdomen. In others, the long axis of the organ may be nearly vertical. The lower end may extend below the level of the navel. There are various other positions between these two extremes.

The inner surface of the stomach is covered with a mucous coat. This contains a surface lining, called *epithelium*, and various glands, which secrete mucus and other substances. Next to this first coat is a so-called *submucous* coat, which is made up of loose connective tissue. Then come three layers of smooth muscle. The fibers of the innermost layer are set obliquely; those of the middle layer are arranged circularly; those of the outer layer run longitudinally. The outer coat of the stomach is made up of a smooth membrane, called the *peritoneum*.

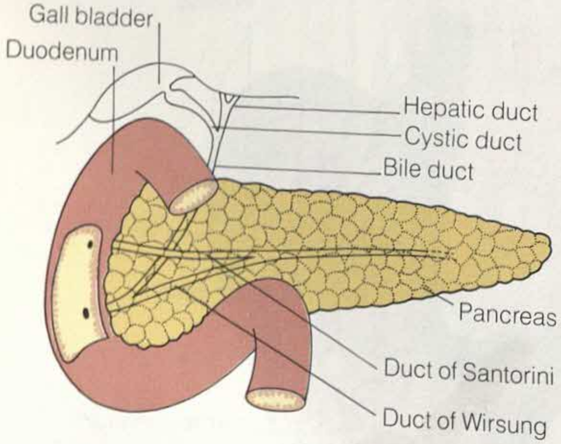
The fundus, or upper part of the stomach, is always filled with entrapped gas. Part of this gas consists of air swallowed together with food. Another part of it is a product of the digestive processes that take place in the stomach. When the part of the stomach below the fundus contains no food, it is like an empty balloon. Its walls are contracted and touch each other. Under such conditions, the inner lining of the organ is thrown into folds, or wrinkles, which are called *rugae*. When food enters the stomach, the walls relax and stretch and the rugae disappear.

THE LIVER



The liver (above) and the pancreas (below) empty their secretions into the duodenum.

THE PANCREAS



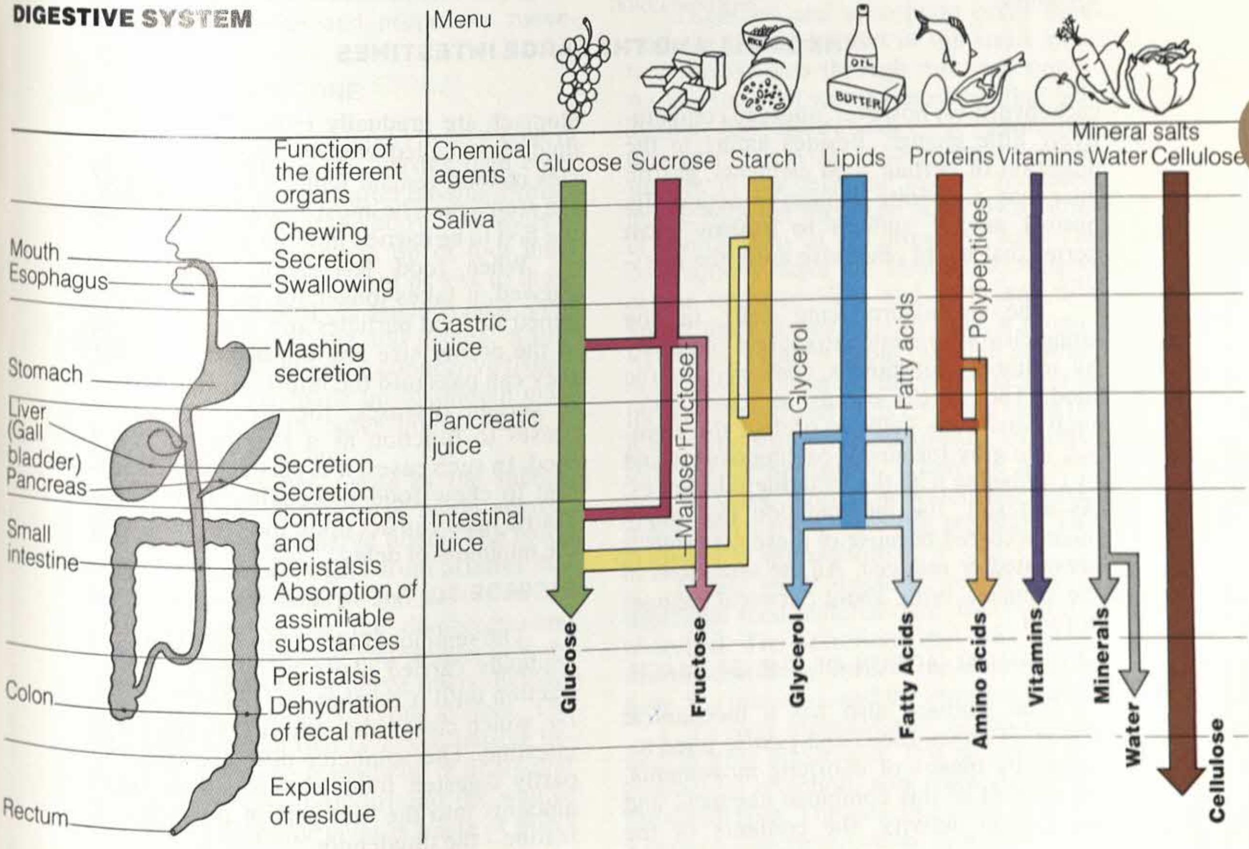
STOMACH SECRETIONS

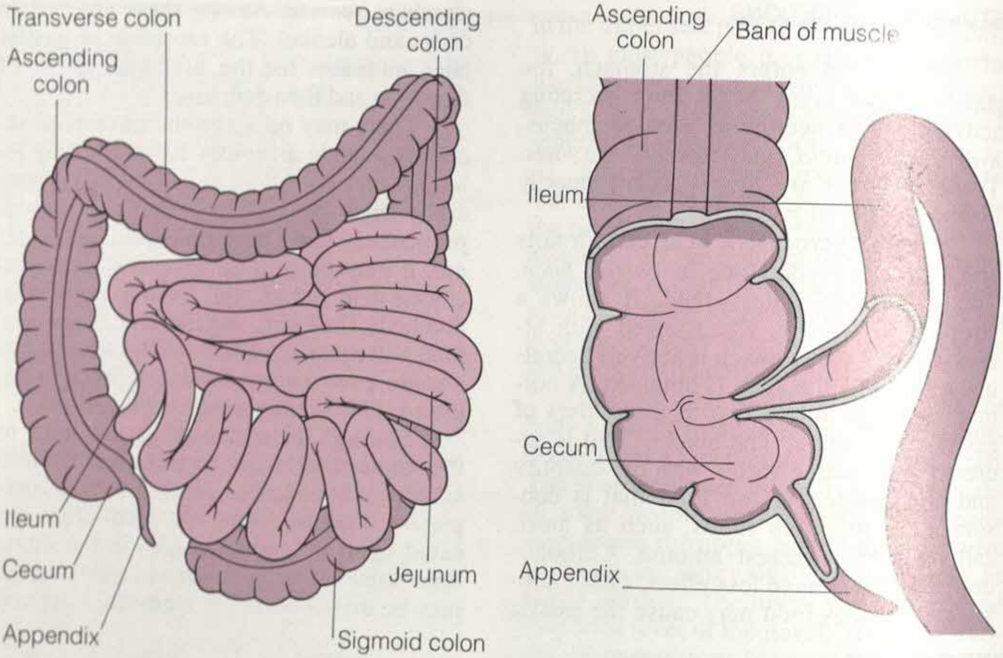
When food enters the stomach, the glands of the organ begin their secreting activities. The secretions include mucus, *hydrochloric acid,* and certain enzymes. These enzymes are *pepsin* and, primarily in young children, *renin.*

Mucus, hydrochloric acid, certain salts and pepsin are contained in *gastric juice.* This is a clear, watery fluid. It shows a strong acid reaction when tested with litmus paper, if the stomach is actively secreting at the time the juice is obtained. A normal individual forms two to three liters of gastric juice daily. The amount that is secreted after eating varies with the quantity and composition of the food that is consumed. Protein-rich foods, such as meat, call forth the greatest amount. Carbohydrates and fats have less effect. Other substances besides food may cause the gastric glands to secrete. Among these are certain drugs and alcohol. The secretion of gastric juice increases for the first hour or so of digestion and then decreases.

There may be a certain amount of secretion even in an empty stomach. This *interdigestive secretion,* as it is called, is generally slight. In certain persons, however, particularly those suffering from peptic ulcer, it may be profuse and rich in hydrochloric acid and pepsin. Even in normal individuals, the sight, smell, or anticipation of food will cause the glands of the stomach to secrete even before food has been swallowed. This is known as *psychic secretion.*

Through the action of gastric juice in the stomach, proteins are broken down into smaller components. They are not completely digested, however, until they are acted upon by various juices in the intestine. Some minerals, such as calcium salts, may be dissolved in the stomach. Fats and





THE SMALL AND THE LARGE INTESTINES

carbohydrates, however, undergo comparatively little change. Besides aiding in the digestion of certain food elements, gastric juice has a definite protective action. Its normal acidity suffices to destroy most germs that might otherwise enter the intestine.

The mucus-producing cells in the stomach are stimulated to secrete copiously by irritating substances contained in the food. The excess mucus secreted under such conditions helps to protect the stomach lining by forming a coating over it and by combining with the irritating substances. As a result, the inflammation that might have occurred because of these materials is prevented or reduced. All the secretions of the stomach bring about chemical changes in food.

MECHANICAL ACTION OF THE STOMACH

The stomach also has a mechanical action. It mixes foods and gastric juice together by means of churning movements. As a result of this combined chemical and mechanical activity, the contents of the stomach are gradually reduced to a semifluid mass called *chyme*. The larger particles of food remain longest in the body of the stomach. The most liquid portions are the first to be carried into the pylorus.

When food has been inadequately chewed, it takes longer for gastric juice to penetrate food particles and to reduce them to the proper size and consistency so that they can pass into the intestine. In the case of certain diseases, the stomach almost ceases to function as a storage place for food. In such cases, it is particularly important to chew food thoroughly so that the gastric juice can act upon the particles with the minimum of delay.

PASSAGE TO THE INTESTINE

The semiliquid chyme in the pylorus is gradually carried along by waves of contraction until it reaches the *pyloric sphincter,* which closes the entrance to the small intestine. The sphincter now relaxes. The partly digested food is expelled in small amounts into the first part of the small intestine—the duodenum.

Food is passed in this way many times before the stomach empties itself. Most of the food has left the stomach three to four hours after the eating of an ordinary meal. However, indigestible residue, such as vegetable fibers, may remain for twenty-four hours or even longer. If there is too much of this indigestible mass, it causes irritation. The contents of the stomach may eventually be vomited.

The amount and the kind of food in the intestine influence the rate at which food passes from the stomach. This useful arrangement prevents the intestine from being crowded with more food that it can tolerate. Certain food elements, particularly fats, are more slowly absorbed from the intestine than others. Fat particles in the intestine cause a hormone called *enterogastrone* to be elaborated from the intestinal wall. The hormone enters the blood stream and acts upon the stomach, slowing up its secreting activities and propulsive movements.

THE SMALL INTESTINE

The digestion of food is completed in the small intestine. The wastes then enter the large intestine and, after passing through it, are expelled from the body. The walls of both intestines are made up of four main layers, corresponding more or less to those of the stomach walls: a mucous coat, containing epithelial tissue and glands; a submucous layer, containing connective tissue; a muscular layer made up of smooth muscle; and a smooth outer lining, which is called the peritoneum.

The connective tissue of the submucous layer has networks of blood vessels, lymph vessels, and nerve fibers. The blood supply is derived largely from arteries that leave the main artery—the aorta—in the abdomen just below the diaphragm and branch out into smaller and smaller vessels. There are two sets of nerve fibers, belonging to the autonomic nervous system. The intestines contain two layers of muscle tissue. The inner one is made up of fibers that are arranged circularly around the wall of the tube. The outer layer is made of fibers running longitudinally.

The small intestine is divided into three parts—the *duodenum*, the *jejunum*, and the *ileum*. The duodenum is less than one-third of a meter in length; the jejunum is from 1½ to 1¾ meters long; the ileum, from 1¾ to 3¼ meters.

The duodenum is different in some respects from the rest of the small intestine. Its wall is thicker and more richly supplied with glands. It receives secretions not only from these glands but also from the liver and pancreas which, as we saw, are located outside of the digestive tract. The duodenum is firmly attached to the posterior wall of the abdominal cavity.

The jejunum and ileum are loosely attached to the posterior abdominal wall by a membrane called the *mesentery*. Their coils can move about within the abdominal cavity.

DIGESTION IN THE SMALL INTESTINE

Digestion and absorption occur especially in the upper part of the small intestine. Foods pass through this area slowly. As a result, the various enzymes that help dissolve food have an adequate opportunity to act on the chyme. This is spread over the surface of the intestine and is intimately mixed with the digestive fluids by a series of contractions of the intestinal wall. The contractions move the semiliquid contents of the intestine back and forth and also knead them. From time to time, a propulsive wave, brought about by other contractions, moves down the intestine and carries the most liquid part of its contents along the tube. This wave motion toward the large intestine is *peristalsis*. There is another type of wave motion in which the waves move backward toward the stomach. This is known as *antiperistalsis*.

In the small intestine, practically all digestible food materials are dissolved and absorbed. The secretions that take part in the process arise from three sources: the liver, the pancreas, and the intestine itself.

The liver provides *bile*, which is emptied into the duodenum. The pancreas also empties its secretion, *pancreatic juice*, into the duodenum. The intestine itself provides a digestive secretion called *intestinal juice*, or *succus entericus*. If any one of these secretions is lacking, the digestive processes are seriously affected. All three types of secretions are alkaline. Therefore, they serve to neutralize acid chyme after it enters the intestine.

Bile, the secretion of the liver, is an amber-colored, bitter fluid. It is stored in the *gall bladder,* under the liver, and is emptied into the duodenum by way of a small tube called the *common bile duct.* About one-half of a liter of bile is secreted daily. One of the principal functions of this secretion is to emulsify fats in the intestinal tract. Once this has taken place, digestive enzymes come into more intimate contact with the fat molecules.

Bile salts, which are among the chief constituents of bile, help to break up globules of fat into very fine particles. They also help make fatty acids soluble. These acids are the disintegration products of fat. Bile serves other purposes. It contributes to the destruction of germs in the upper intestinal tract. It also helps hold various substances other than fats in solution.

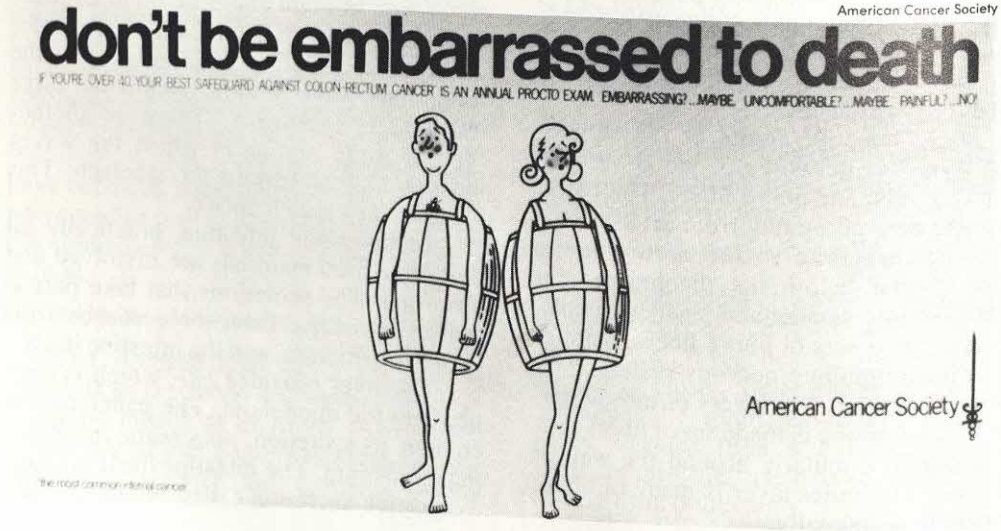
Pancreatic juice secretion is brought about in a rather roundabout way. The presence of acid chyme and certain disintegration products of foods stimulates the glands in the intestinal wall to secrete the hormones *secretin* and *pancreozymin.* These, in turn, cause the pancreas to secrete pancreatic juice. About one-half of a liter of pancreatic juice is produced daily by the pancreas of a normal person.

Pancreatic juice is a clear fluid that feels slippery to the touch. It contains sodium carbonate in addition to substances that aid in the solution of carbohydrates, fats, and proteins. The digestive enzymes contained in pancreatic juice are very potent. An enzyme called *amylase* acts on starch to change it into a much simpler carbohydrate—maltose. This is a continuation of the action begun in the mouth by ptyalin. Two other enzymes—*trypsin* and *chymotrypsin*—act on proteins to break down the protein molecules, which are still large even after digestion in the stomach. Another pancreatic enzyme, *lipase,* acts on fats. It splits the fat molecules into fatty acids and glycerin. Fatty acids, as we have seen, are made soluble by bile salts and in this form pass readily through the lining of the intestine.

Intestinal juice is secreted by glands in the walls of the upper part of the intestine. Secretion takes place when these glands are stimulated by acids and by various diges-

People over 40 years of age have increased chances of developing cancer of the colon. For these people, a yearly proctoscopic examination is a must. The examination is somewhat uncomfortable—but it can be a lifesaver.

American Cancer Society


don't be embarrassed to death
IF YOU'RE OVER 40 YOUR BEST SAFEGUARD AGAINST COLON-RECTUM CANCER* IS AN ANNUAL PROCTO EXAM. EMBARRASSING?...MAYBE. UNCOMFORTABLE?...MAYBE. PAINFUL?...NO!
*the most common internal cancer
American Cancer Society

tive products that are derived from food. Hormones may also take part in the stimulation process. As much as three to four liters of intestinal juice may be formed daily.

Intestinal juice contains sodium chloride (table salt), sodium carbonate, and various enzymes, each of which has a specific action. One group of enzymes acts on sucrose and lactose, as well as on the maltose derived from the salivary and pancreatic digestion of starch. It breaks these sugars down into simple sugars. Another enzyme acts on partially digested proteins, converting them into amino acids. The enzyme lipase, like the lipase found in pancreatic juice, acts on emulsified fat in such a way as to liberate the fatty acids.

ABSORPTION IN THE SMALL INTESTINE

After all these chemical transformations have been completed, starches and complex sugars have been broken down to simple sugars, fats to fatty acids, and glycerin, and proteins to amino acids. All these end products of digestion can now be readily absorbed through the walls of the intestine.

The lining of the intestine is studded with millions of tiny outpouchings of epithelium called *villi.* Villi greatly increase the absorptive area across which the transfer of substances can take place. By means of certain whiplike movements and pumping movements, the villi stir up the fluid immediately surrounding them and bring a fresh supply of substances in contact with their surface. The pumping action involved probably improves the local circulation and also regulates the permeability of the absorbing surface.

By the time the intestinal contents reach the lower part of the small intestine, absorption is practically complete. Bacteria in the lower part of the small intestine cause further decomposition of its contents. A certain proportion of the products of decomposition resulting from bacterial action may be absorbed.

PASSAGE TO THE LARGE INTESTINE

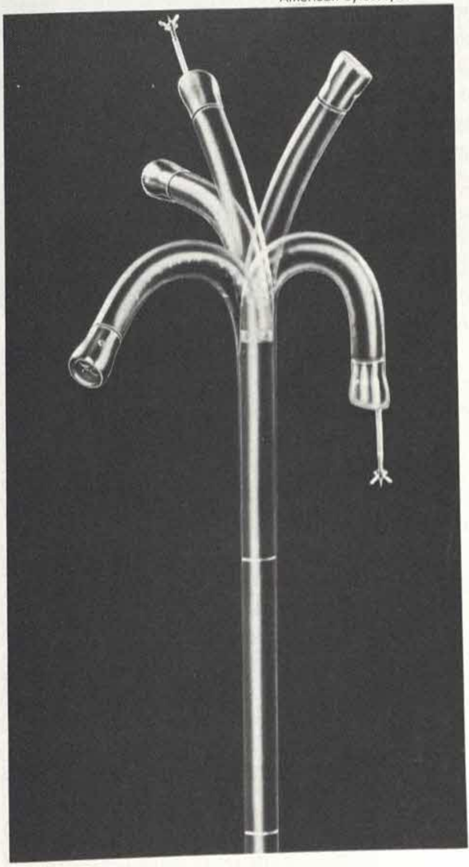
The small intestine opens more or less at right angles into the large intestine. A structure called the *ileocaecal,* or *colic, valve* is located at this junction. It is made up of two liplike folds that project into the large intestine. There is a narrow slit between them.

The ileocaecal valve permits chyme to be emptied into the large intestine but makes it very difficult for chyme in the large intestine to return to the small one. Chyme is not passed through the ileocaecal valve until digestion is virtually complete. The normal emptying time of the small intestine is from five to eight hours.

When the chyme reaches the large intestine, it contains cellular debris, bacteria, indigestible food residue, fats, and some minerals, and water. A great deal of the

The colonoscope is a thin, very flexible rod that allows a physician to see the entire colon during an examination. It can also be used to remove some growths from the colon.

American Cytoscope Makers



water is absorbed as these materials pass through the large intestine and ultimately become the semisolid *feces* that are expelled from the body. Even the feces have a comparatively high water content: from two thirds to three quarters of the total weight.

THE LARGE INTESTINE

The large intestine is made up of the caecum, the colon, and the rectum.

The *caecum,* just below the junction of the small and large intestine, is a short, dead-end pouch a few centimeters long. A small, fingerlike tubular projection, called the *vermiform appendix,* extends from the lower part of the caecum. We shall tell later about the part played by the appendix under abnormal conditions.

The *colon* is the part of the large intestine extending from the caecum to the rectum. First the colon passes vertically upward for about 15 centimeters on the right side of the body. This is the *ascending colon.* When it reaches the liver, it makes a sharp turn (approximately at right angles) and crosses the belly below the stomach, until it reaches the spleen. This is the *transverse colon.* It makes another sharp turn and then passes vertically downward for 15 centimeters or so on the left side of the body – the *descending colon.* Finally it forms a loop called the *sigmoid flexure,* or *sigmoid colon,* extending to the rectum.

The *rectum,* the last section of the large intestine, is divided into two parts: the rectum proper and the anal canal. The canal leads to an aperture called the *anus.* This is kept closed by the contraction of two sphincters, which relax only when fecal matter is passed from the body.

The longitudinal muscle fibers of the caecum and colon are in three bands. Since these bands are shorter than the underlying layer, they cause the caecum and colon to be drawn into a succession of tucks and sacs, presenting a rather curious caterpillar-like appearance.

After the contents of the ileum pass through the ileocaecal valve, they collect in the caecum. They then pass upward into the ascending colon. It is not known how this is brought about. It may be due in part to the overflowing of material in the caecum. However, in many cases this material is found in the ascending colon before the caecum is filled. The caecum is capable of certain movements, as is shown by slow changes in its shape. However, these movements would not suffice to propel the contents of the caecum upward into the ascending colon.

COLON MOVEMENTS

The movements of the colon are generally sluggish. From time to time, however, a vigorous sort of movement, called *mass peristalsis,* takes place. It sweeps the contents of the colon along for considerable distances. There are generally only two or three of these movements a day. They are most likely to occur after a meal, particularly breakfast. The area that is involved first dilates and shortens, then contracts. The contractions begin in the part of the colon nearest the small intestine and progress toward the anal canal. These mass peristaltic movements, taking place periodically, as we mentioned above, are chiefly responsible for the movement of fecal matter through the parts of the colon and into the rectum.

The fecal masses are finally propelled into the rectum. The rectum becomes distended and then contracts, producing a definite stimulus. The first stimulus may be too weak to attract a person's attention, but the stimuli grow stronger as the contractions of the rectum increase in vigor. When a person is ready to pass the fecal mass from his body, he voluntarily relaxes the *anal sphincters,* the last sphincters in the digestive tract. The anal canal is shortened. The contraction of the abdominal muscles aids in emptying the rectum.

The urge to pass feces is a reflex. It can be conditioned by proper dietary habits and by ordering one's life so that one can respond to the urge to defecate when the appropriate stimulus occurs.

HUNGER

Besides possessing an effective mechanism for deriving nutrition from foodstuffs,

UPI

For some very obese persons, weight reduction can be achieved by a colon-bypass operation. This is, however, a serious procedure to be considered only as a last resort.

man has a definite drive to eat – a drive that we call *hunger*. One begins to experience a sensation of hunger when the stomach is practically empty. The sensation becomes more intense as time passes. Besides a feeling of emptiness, there are definite "hunger pangs," due to powerful contractions of the stomach. They may be sustained for as long as thirty seconds. They grow more and more intense the first two or three days of a prolonged fast. After that period of time, they are less pronounced.

An individual may experience hunger for a specific food. Animals, for example, have been known to travel long distances in search of salt. In many cases, dietary craving is associated with certain diseases, or from certain deficiencies in the diet.

Appetite, or the desire food, is entirely different from hunger. It reflects a certain state of mind. This is based on previous pleasurable experiences associated with eating. Appetite may go hand in hand with hunger, but this is not necessarily the case. Hunger is the inevitable consequence of not eating, but a starving person may lose his appetite.

The survival time in starvation depends upon the health and previous diet of the person deprived of food. It also depends upon his activity. The less active he is, the longer he can survive. There are numerous instances of fasting individuals doing without food for more than one month. Fasting, however, can have serious effects and should not be undertaken – for example, as a weight-reducing plan – without medical supervision.

DISORDERS OF THE DIGESTIVE TRACT

When a person's digestive tract is normal in structure and functions normally, the processes that we have described go on day after day without incident. If there is any abnormality in structure or function, serious consequences can arise.

Congenital disorders. When a baby is born with a cleft palate, or incomplete closure between the roof of the mouth and the nasal cavity, it cannot suck normally. If it tries to swallow milk, the fluid is apt to run out of the nose. Occasionally, infants are born with an inadequate stomach outlet. Such babies can suck and swallow normally, but they cannot obtain any nourishment from food because it cannot pass into the intestine from the stomach.

Stomachache. When different parts of the alimentary canal fail to cooperate with one another, digestive disorders may arise. Sometimes one eats so much rich food that the stomach fails to pass it into the intestine, probably because of stimuli that arise in the intestine. The pyloric sphincter at the opening between the stomach and intestine fails to relax. The contents of the stomach cannot pass through the sphincter into the small intestine.

The contractions of the stomach become continually stronger. Eventually, they will be felt by the sufferer and he will complain of stomachache. If the sphincter muscle does not ultimately relax, a sensation of *nausea* arises. When it becomes sufficiently strong, the upper part of the stomach relaxes and the lower part (pylorus) contracts. The muscles of the abdomen involved in expiration (breathing out) also contract. The contents of the stomach are then *vomited* into the mouth.

Emotional disturbances may affect the digestive tract. A child who cries may "get a lump in this throat" and be unable to swallow. This feeling is due to a spasm at the upper end of the esophagus. Fear causes the mouth to become dry and the saliva to become thick. One loses all desire for food. Fear can also cause the stomach to lessen its secretions or stop them entirely. Under such conditions one may have difficulty in swallowing food, and the contents of the stomach may be vomited. Grief or protracted worry may have similar effects.

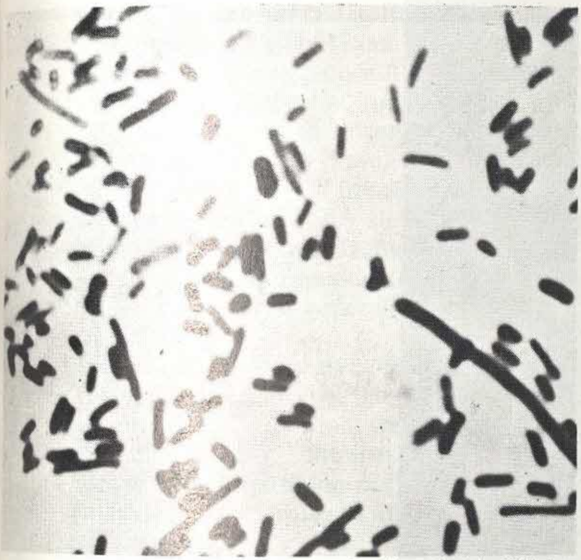
Other emotional factors may contribute to an increased flow of saliva, heightened secretion, and more active movements of the stomach. This frequently happens when we look at food that we enjoy eating, or when we smell delightful odors that are coming from the kitchen.

Constipation. Constipation is a fairly general complaint among the population at large. Some people imagine they are constipated because they fail to move their bowels daily. It is true that most persons have at least one bowel movement every day, yet there are perfectly normal people who move their bowels once every two or three days. The frequency and character of bowel movements depend on a variety of factors, such as the amount of roughage contained in the diet, the quantity of water that is consumed, and the motility of the stomach, small intestine, and colon.

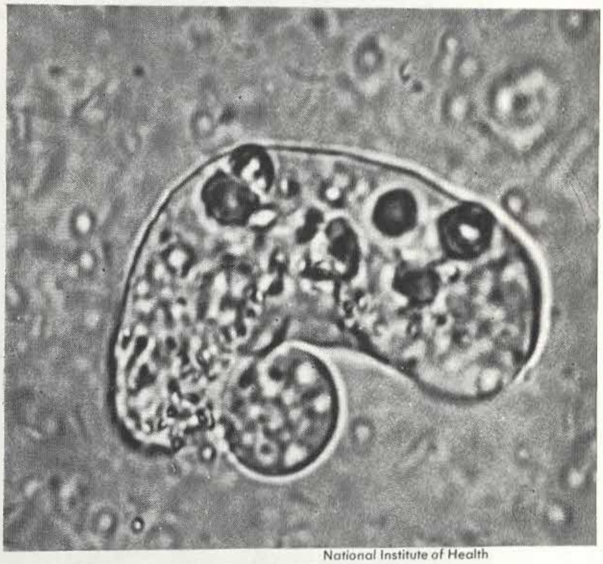
A bona fide case of constipation may be due to faulty habits. If one delays defecation for long periods at a time, the rectum may come to tolerate the increased bulk of fecal matter it contains. The necessary stimuli may become feebler or may be entirely absent. As feces collect not only in the rectum but in the part of the colon nearest to it, the liquid portion of the waste matter is absorbed. The feces then become dry and hard, and it becomes difficult to pass them out of the body. A drastic change in habits will do more to cure a condition of this kind than the indiscriminate use of laxatives.

Constipation may be due to other factors. It may be difficult to evacuate because of weakness in the abdominal muscles that are involved in the process. The diet may contain too little bulk or too little fluid. In the condition known as *spastic colon* the colon contracts excessively and remains firmly contracted. In such cases one should seek the advice of one's physician

Diarrhea. In the condition known as *diarrhea,* the bowels move too frequently and the stools are too soft. This happens when the contents of the intestines are



Armed Forces Institute of Pathology



National Institute of Health

Left: the bacteria shown belong to the genus *Shigella.* They cause bacillary dysentery in humans. Right: the parasitic ameba known as *Entamoeba histolytica* that causes amebic dysentery in humans.

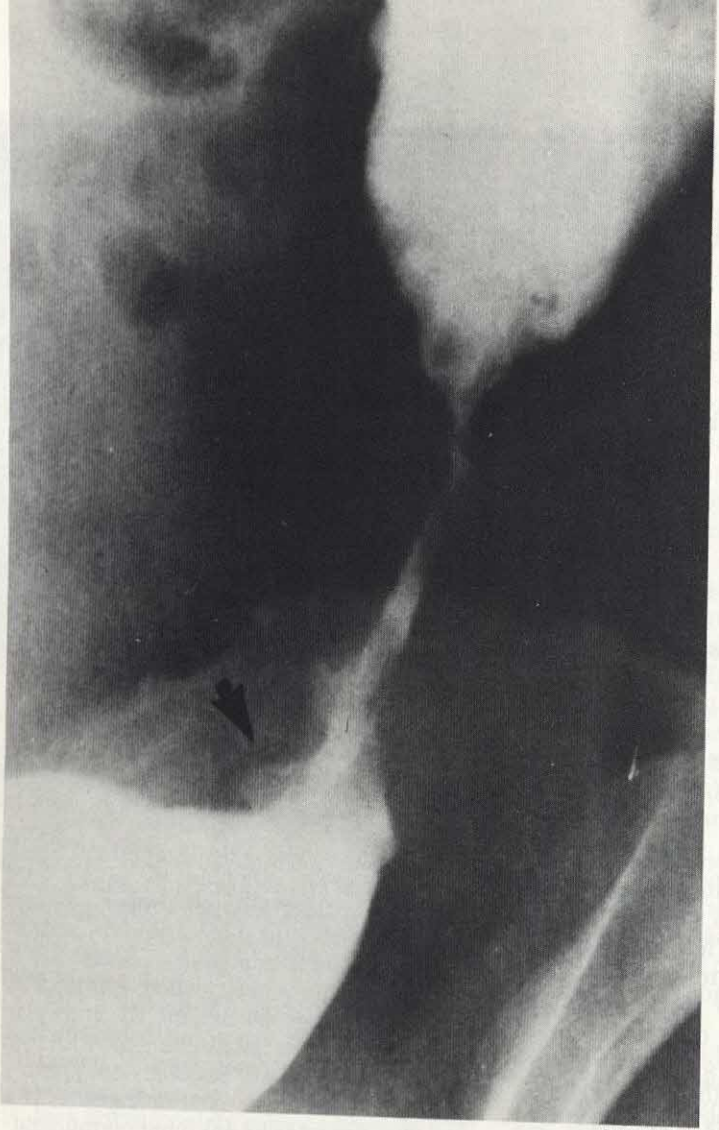
passed through the large bowel too rapidly and not enough water is absorbed through the bowel walls. Diarrhea may be caused by eating unripe fruit or infected food or drink. It may also be due to emotional disturbances, such as fear or rage. It may be the symptom of a serious disease, such as typhoid or cancer. If there is blood in the stools or if they are black, there is particular cause for alarm. Mild cases of diarrhea may often be cured by diet. In severe cases, a physician should be consulted.

Dysentery. The name dysentery is generally applied to two specific diseases—*bacillary dysentery* and *amebic dysentery.*

Bacillary dysentery is caused by certain bacterial species belonging to the genus *Shigella.* The bacteria gain entry to the gastrointestinal tract in contaminated food or drink and they multiply in the intestines. They produce toxins that inflame the tissues. The symptoms are painful and bloody diarrhea, high fever, and extreme thirst. The disease may result in perforation of the intestinal wall. The nervous system may also be affected.

Bacillary dysentery is particularly common in the tropics, but is likely to occur whenever great numbers of people are crowded together without proper sanitary facilities. Sulfa drugs and antitoxin serums have been used to combat the disease.

A parasitic ameba called *Entamoeba histolytica* brings on amebic dysentery in man. This ameba is discharged with the feces of sufferers and becomes encysted—that is, enclosed in a cyst, or capsule. If a person eats or drinks anything contaminated with such encysted amebas, the capsules resist digestion until the parasites have penetrated the lower part of the intestines. The symptoms are frequent and bloody stools, headache, nausea, and high fever. The amebas may produce ulcers and abscesses in the wall of the colon. They may enter the blood stream and spread throughout the body. As in the case of bacillary dysentery, amebic dysentery is particularly common in the tropics. It is also found in areas where crowded conditions are combined with lack of sanitary precautions. The antibiotics aureomycin and terramycin have proved effective in treating this condition.



A severe constriction of the colon, such as that shown in this X ray, prevents the passage of fecal matter and is a very serious medical problem.

Eastman Kodak

Appendicitis. Perhaps the most familiar of the serious disorders affecting the gastrointestinal tract is appendicitis, or inflammation of the vermiform appendix. This outgrowth of the caecum serves no particular purpose in man. It is hollow, can secrete mucus, and is normally able to empty its contents into the caecum. However, deposits may be built up in it or its outlet may be obstructed. If these conditions exist, drainage will be inadequate. Changes in the lining of the appendix will then take place. Bacteria will invade the wall of the organ and inflammation will set in. When this occurs, a person is said to have appendicitis.

Inflammation anywhere along the wall of the intestine affects all other parts of the alimentary canal. For example, if the appendix is involved, the stomach may be unable to empty its contents into the intestine. The sufferer will become sick at the stomach and will vomit. Nausea is one of the principal symptoms of appendicitis. There are various others. The patient often feels intense pain, first in the region of the navel and then in the lower right part of the abdomen. The abdomen, in the vicinity of the appendix, is sensitive to the touch. Its wall is tense. The white blood cell count is high.

If a person thinks he has some of these

symptoms, he should refrain from taking laxatives until a physician has a chance to determine whether or not he is suffering from appendicitis. The mortality rate from the disease is much lower among patients who see a physician during the first hours of their illness than it is among those who wait until they are critically ill before they decide to call a doctor. If the physician is alerted in time, an appendectomy, or removal of the appendix, is generally a routine operation.

Ulcers. Peptic ulcer is another serious complaint involving the gastrointestinal tract. In this condition, the pepsin and hydrochloric acid contained in the gastric juice act on the lining of the duodenum or stomach. As a result, tissue in these organs is destroyed.

The most common site of peptic ulcer is the first part of the duodenum, just beyond the outlet of the stomach. An ulcer in this area is called a *duodenal ulcer*. A *gastric ulcer* is one that develops in the stomach. In both types of peptic ulcers, the patient complains of a burning sensation or pain in the upper part of the abdomen. It tends to recur at regular intervals and is made worse by eating abrasive foods such as celery. A glass of milk sometimes brings relief from the distress.

A person who feels pain in the abdomen at more or less regular intervals should suspect the existence of a peptic ulcer and should see his doctor at once. The destruction of the lining of the duodenum or stomach at the site of an ulcer may have serious consequences. Bleeding may occur and not be detected until severe blood loss has occurred. The walls of the duodenum or stomach may be perforated, causing the contents of the organ to spill out into the abdominal cavity. The membrane lining this cavity – the peritoneum – may be infected as a consequence, and the very dangerous condition known as *peritonitis* may result. Ulcers may become malignant. It is thought that in some instances cancer of the stomach arises from pre-existing ulcers.

Gallstones. The digestive processes may be seriously affected by the formations called *gallstones*. These are irregularly shaped bodies found in the gall bladder or the bile duct. They contain cholesterol, pigments, bile salts, and calcium in varying proportions. Various factors are involved in the formation of gallstones. Faulty metabolism may be one cause, or the gall bladder may be infected, or it may fail to empty itself with completeness and regularity.

Gallstones are more common in women than in men. They are particularly likely to be found in women who have borne children. The presence of stones in the gall bladder may cause no symptoms in some people. In others there may be an attack of colicky pain in the upper part of the abdomen, on the right side, from time to time. The pain often radiates to the back.

Stones may be single or multiple, large or small. Sometimes a stone may pass from the gall bladder into the common bile duct and may obstruct the passage of bile into the intestine. Pain and nausea follow. The skin turns yellow because the bile pigments are released into the blood stream. Their absence in the intestinal tract causes light yellow stools. There is no way to dissolve gallstones while they remain in the gall bladder or bile duct. They can be removed surgically. Often, the entire gall bladder is removed.

Cancer. The most common sites of cancer of the gastrointestinal tract are the stomach and the colon. Cancer of this type is most common in older people, though it sometimes attacks others. The passage of blood in the stools is a warning symptom. So is any marked change in the character or the regularity of bowel movements. Early recognition is essential for the successful treatment of any cancer.

Summary. This brief survey of the disorders that may affect the digestive tract has given only a sketchy idea of the many unpleasant things that can happen when something goes wrong with this vital system. It is the avenue through which all the food elements required for health gain access to the tissues of the body. It is supremely important, therefore, to keep it functioning properly through regular habits, proper diet, and prompt medical attention if symptoms should occur.

TEETH

by Lon W. Morrey

A famous character in fiction once remarked, after losing several teeth in a fight, that "every tooth in a man's head is more valuable than a diamond." He did not exaggerate. For the teeth, stationed at the very entrance to the alimentary canal, serve to tear and grind our food and to prepare it in this way for its passage through the stomach and the intestines. One could get along without teeth after a fashion by limiting oneself to certain kinds of foods, but one's diet would be very restricted.

SOLID STRUCTURES

The teeth are solid structures. They have been made hard by the embedding of calcium, phosphorus, magnesium, and other mineral salts in an organic material. They are firmly anchored in bony sockets in the upper and lower jaws. There are four types of tissue in teeth: *enamel,* which covers the crown or visible part of the tooth, is the hardest substance in the body; *dentine,* which is harder and denser than bone, makes up the main mass of the tooth; *cementum,* a bonelike substance, covers the dentine in the root; and *pulp,* which occupies the center of the tooth and contains nerves, arteries, veins, and lymphatic vessels. The *periodontal membrane* is a layer of soft tissue between the tooth root and the jaw. It holds the tooth in place and acts as a cushion to lessen the force of impact that takes place in chewing. "Periodontal" means "around the teeth."

DECIDUOUS TEETH

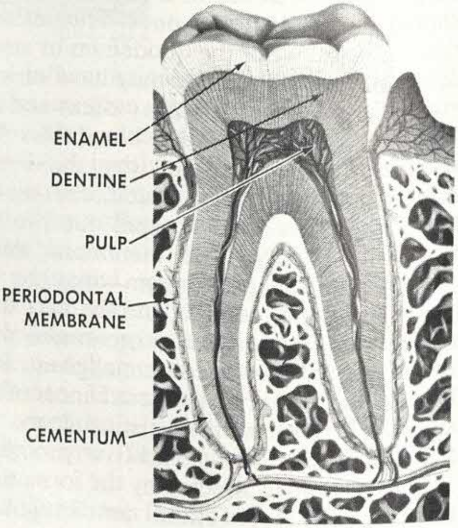
There are twenty teeth in the first set—the so-called milk teeth. These are also called the *deciduous* (falling-off") *teeth,* because they are shed after several years and are replaced by permanent teeth.

Tooth buds begin to form in the embryo as early as the sixth week of prenatal life. They begin to harden about the sixteenth week. At birth, a considerable part of the crowns not only of the deciduous teeth but also of the first permanent molars have already been formed.

The tables show the approximate times when deciduous teeth erupt and are shed and when permanent teeth erupt. These are average figures. There is no particular cause for alarm if the teeth of a given child do not follow this growth pattern. The variations even in normal children are often quite wide.

The care of deciduous teeth should not be neglected, even though such teeth will be replaced. The first teeth are necessary for proper chewing. They aid in speech. They give form and symmetry to the face. They act as guides for the eruption of the permanent teeth that are forming beneath them. When a deciduous tooth is lost too early, the adjacent and opposing teeth may shift out of position, thus weakening the proper arrangement of teeth in the mouth. The dentist may prevent permanent damage in such a case by inserting a device called a *space maintainer*. This preserves

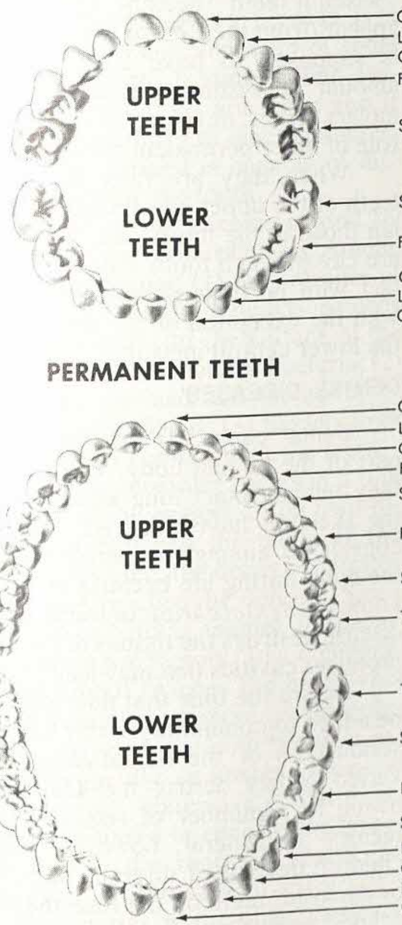
Structure of a tooth with two roots, showing the four types of tooth tissue and the membrane around the tooth. The jawbone and blood vessels are also shown.



the alignment of the first set and provides space for the eruption of the permanent teeth.

PERMANENT TEETH

The second, or *permanent*, set of teeth contains thirty-two teeth. The eight front teeth – the *central* and *lateral* (side) *incisors* – are cutting instruments. Flanking the incisors are the four *cuspids*, which have a long, heavy root and a sharp point for tearing food. They are also known as *canines*, or eyeteeth. Next to the cuspids are the eight *bicuspids*, or *premolars*. There are two on each side of the upper and the lower jaw. As their name implies, they have two cusps, or pointed projections, on each crown. The bicuspids tear and crush food. Finally, in the back part of the mouth we find the twelve *molars*, in groups of three on each side of the upper and lower jaw. The molars have two or three roots and

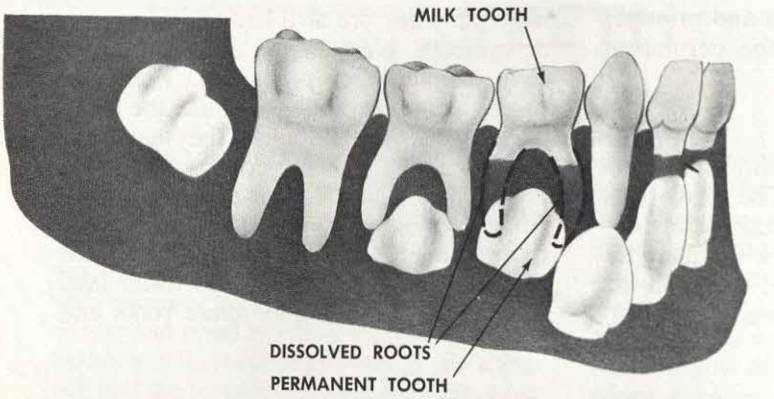


DECIDUOUS TEETH (MILK TEETH)

		ERUPTION (age in months)	SHEDDING (age in years)
UPPER TEETH	CENTRAL INCISOR	7½	7½
	LATERAL INCISOR	9	8
	CUSPID	18	11½
	FIRST MOLAR	14	10½
	SECOND MOLAR	24	10½
LOWER TEETH	SECOND MOLAR	20	11
	FIRST MOLAR	12	10
	CUSPID	16	9½
	LATERAL INCISOR	7	7
	CENTRAL INCISOR	6	6

PERMANENT TEETH

		ERUPTION (age in years)
UPPER TEETH	CENTRAL INCISOR	7-8
	LATERAL INCISOR	8-9
	CUSPID	11-12
	FIRST BICUSPID	10-11
	SECOND BICUSPID	10-12
	FIRST MOLAR	6-7
	SECOND MOLAR	12-13
	THIRD MOLAR (WISDOM TOOTH)	17-21
LOWER TEETH	THIRD MOLAR (WISDOM TOOTH)	17-21
	SECOND MOLAR	11-13
	FIRST MOLAR	6-7
	SECOND BICUSPID	11-12
	FIRST BICUSPID	10-12
	CUSPID	9-10
	LATERAL INCISOR	7-8
	CENTRAL INCISOR	6-7



Teeth of the typical six-year-old. The milk teeth are exposed, but the permanent teeth are not yet out. The broken lines indicate the dissolved roots of one of the milk teeth.

several cusps for grinding food so that it will be suitable for swallowing and digesting. The third molars, the hindmost teeth in the mouth, are also known as the *wisdom teeth*. As the diagram shows, the teeth in each jaw form an arch, called the *dental arch*.

The first of the permanent teeth—the first permanent molars—have already been partially formed within the child's jaws at birth. They erupt when he is about six years of age, shortly before the large upper front teeth—the central incisors—appear. During the early months of the baby's life, the permanent incisors and cuspids begin to calcify within the jaws. From this point until about the age of 12, the jaws are constantly at work building teeth.

The first permanent molars are the most important teeth in the dental arch because they act as the guide and the keystone for the remaining permanent teeth. There are four of these molars, one on each side of the upper and the lower jaw. They erupt behind the last deciduous molars. Because they are often mistaken by parents for deciduous teeth, their care is often neglected. As a result, the entire permanent dental arch is endangered.

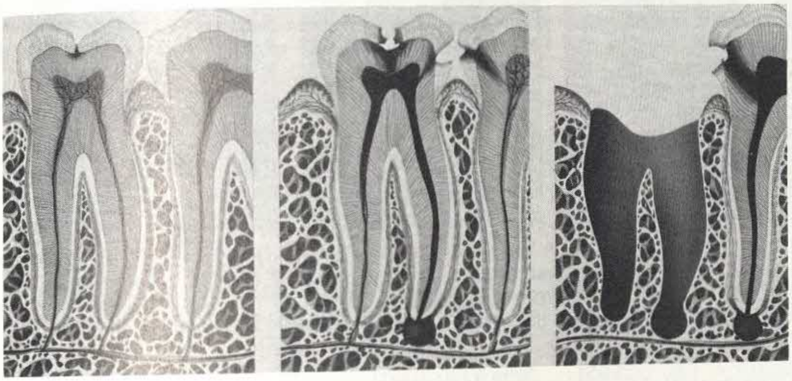
By the time the first permanent molars have erupted, the jaws have grown to such an extent that the deciduous front teeth are not so close together as before. Spaces appear between them. This is really most fortunate, because the permanent teeth are larger than the deciduous set and require more room. If all goes well, they will fit snugly in the spaces left for them. The third molars are the last of the permanent teeth to erupt. They are sometimes called the "wisdom teeth" because by the time they appear (from the 17th to the 21st year), one is supposed to have acquired a certain amount of wisdom. Sometimes the third molars never develop. This may also be true of other permanent teeth.

When they are fully developed, the teeth of the upper jaw should slightly overlap those in the lower one. When the jaws are closed, each tooth should come in contact with portions of two opposing teeth, with the exception of the third molars and the lower central incisors.

DENTAL DISEASES

Dental caries. Teeth are the hardest part of the human body. Even after death they remain intact long after the bones of the skeleton have decayed. Yet they are considered among the perishable parts of the body during life because of the disease known as *dental caries,* or tooth decay. This disease destroys the tissues of the tooth and produces cavities that may lead to its death.

Before the time that fluorides began to be added to community water supplies, the seriousness of the dental-caries situation varied widely across the United States, owing to a number of regional and local factors. In general, however, half of all children developed three or more carious, or decayed, teeth by the time they reached school age. Very few young people remained free from caries at age 16. The incidence of dental caries is decreasing, but it still remains a major health problem.



How teeth may be lost. Far left: decay has penetrated tooth enamel. Center: decay has attacked the dentine of one tooth and has killed the pulp, causing an abscess to form. Near left: the badly decayed tooth has been extracted. However, an abscess is starting to form in the adjacent tooth.

Dental caries is caused by an acid that is formed when bacteria act on fermentable carbohydrates, principally sugar, in the mouth. This acid-producing process is a chemical chain reaction, made up of some fifteen different steps. It starts within seconds after carbohydrates are eaten and it continues for from thirty to ninety minutes. The acid that is formed is capable of dissolving the enamel of the tooth.

The extent of the damage caused by the acid depends on various factors. Among these are the following: (1) the presence of dental *plaques*—sticky, gluelike patches that cling tenaciously to the surface of the tooth and afford protection for bacteria; (2) the strength of the acid and the ability of the saliva to neutralize it; (3) the length of time the acid is in contact with the teeth.

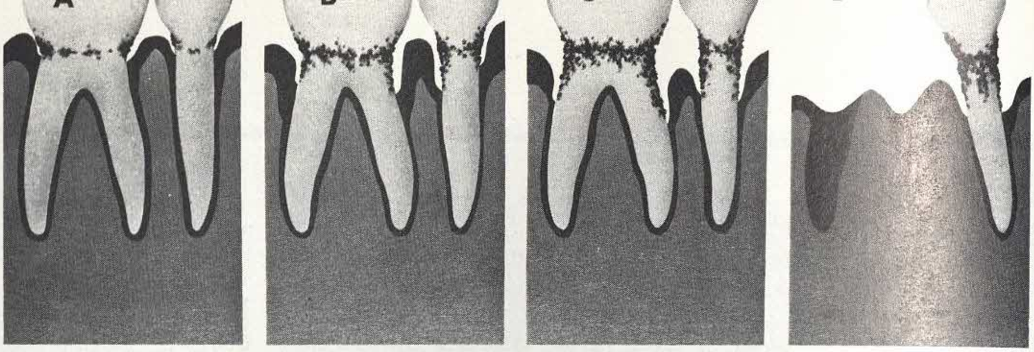
Tooth decay generally begins in a tiny fissure or flaw of the enamel, or on hard-to-get-at surfaces between the teeth. If the condition is neglected, the decay penetrates the enamel and reaches the dentine. Since dentine is not so hard as enamel, the decay now advances more rapidly. In a comparatively short time it reaches the blood vessels, lymph vessels, and nerves in the pulp. Upon being exposed, the pulp becomes infected and frequently an abscess forms at the tip of the root. Extensive dental treatment is then required to remove the infection and restore the tooth to health. In many cases it is necessary to extract the tooth. Dental caries is the chief cause of tooth loss in young persons. A chipped bone or broken skin may heal itself, but decaying tooth enamel cannot be regenerated in this way. All the dentist can do is to remove the decayed part of the tooth and to fill the resulting cavity. Prevention is the only cure for dental decay.

Periodontal diseases. Diseases of the gums and of the bones that support the teeth are called *periodontal diseases,* because they involve structures surrounding the teeth. When these structures are affected and give way, the teeth become loosened. They may even fall out if treatment is not started early enough. The periodontal diseases are most likely to attack those over thirty-five years of age. These disorders cause more tooth loss than does dental caries.

One of the principal periodontal diseases is *gingivitis,* an inflammation of the gingivae, or gums. Among the causes of this ailment are the accumulation of tartar deposits on the teeth, injury, and poor toothbrushing. Bleeding is a frequent symptom.

When gingivitis is not treated, it often leads to *periodontitis,* frequently called *pyorrhea.* The gums that normally hug the tooth loosen, forming a pocket that fills with bacteria and pus. The supporting bone itself may be affected. The tooth, with its support thus weakened, may be lost, unless treatment is begun early enough.

Vincent's infection, another periodontal disease, attacks not only the gums but other parts of the mouth and throat as well. During World War I, it was called "trench mouth" because it was so prevalent among soldiers in the trenches. Although the exact cause of the disorder is not known, unhygienic conditions and lowered tissue resist-



The effects of pyorrhea. A. Food and tartar deposits have irritated the gums, causing them to begin to withdraw from the teeth. B. Pyorrhea has caused further destruction. C. Pyorrhea has destroyed most of the tissues around one tooth and has weakened the other. D. One tooth is lost, the other weakened.

ance are important factors.. Symptoms of acute Vincent's infection are inflammation and ulceration of the gums, an offensive odor, pain, and excessive bleeding. The disorder usually yields readily to treatment by the dentist.

The *canker sore* is another painful oral disorder. It occurs, usually in the form of a small ulcer, in the mucous membranes of the mouth. Because nerve endings may lie immediately beneath the ulcer, there is often extreme pain. Fortunately dental treatment brings relief. The sores usually heal in from eight to ten days.

MALOCCLUSIONS

Teeth that are irregularly spaced or that do not meet properly when the mouth is closed are said to be in *malocclusion.* In one study of more than 1,000 school-age children, about 30 per cent were found to need some form of treatment for this condition. Other studies have shown that an even higher percentage of the population probably has a certain degree of malocclusion.

Malocclusion may be due to certain hereditary factors: narrow dental arches; the eruption of the teeth before the jaw has grown sufficiently; the premature shedding or prolonged retention of deciduous teeth. Certain undesirable habits may also account for the condition. Among these are thumb- or finger-sucking, lip-sucking, and sleeping positions that result in unusual pressure on the jaws. In the case of thumb-sucking, dentists generally agree that if the habit is stopped before the age of five, there is a good chance that the teeth will return to normal position.

Malocclusion may interfere with proper mastication, cause serious facial deformities, and contribute to speech defects or periodontal diseases. Treatment varies with individual cases. It may involve the use of space maintainers, the extraction of some teeth to relieve crowding, and the application of fixed wire bands to guide the teeth into the proper position. Some minor cases can be corrected in a few months. More severe cases may require a few years.

CARE OF THE TEETH

The emphasis in dentistry today is on prevention rather than treatment. An example of this trend is the fluoridation of community water supplies in order to reduce the rate of dental decay.

Fluoridation is the controlled addition of some form of fluoride to the water—usually one part of fluoride is used to one million parts of water. Studies have shown that this public-health measure will reduce the number of dental-caries cases by something like two-thirds.

When children living in the city of Evanston, Illinois, were subjected to fluoridation over a period of years, researchers found notable decreases in the number of decayed, missing, and filled teeth. Six-, seven- and eight-year-olds showed an improvement of 91.3 per cent, 64.57 per cent, and 62.60 per cent, respectively, compared to similar age groups examined in the days before fluoridation was introduced. In the control city of Oak Park, Illinois, whose water supply was not fluoridated, similar age groups were examined. There had been no significant change in the rate of decay in the six- and eight-year-olds over the years, but there had been an increase in the case of the seven-year-olds.

In communities that have no central water system, the application of a fluoride solution directly on children's teeth has proved helpful. However, such individual treatment does not produce as satisfactory results as fluoridating the water supply.

Another preventive measure that is stressed by the dental profession is tooth brushing. The toothbrush removes food particles and other deposits from between the teeth and from the crevices of the chewing surfaces. It also helps prevent tartar deposits from forming on the teeth and contributes to the health of the gums.

The teeth should be brushed immediately after a meal or a snack (particularly a sweet snack). If it is not possible to do so, the mouth should be rinsed with water.

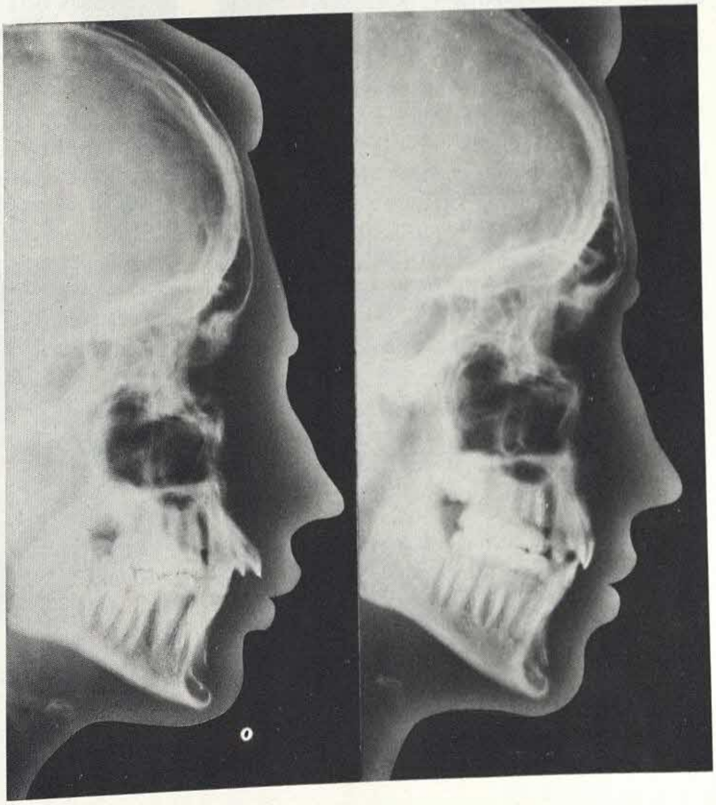
The primary purpose of a *dentifrice*—a powder, paste, or liquid used in cleaning the teeth—is to help the brush clean the teeth. Clinical studies are being conducted on other dentifrices.

Following are some rules for brushing the teeth: (1) brush the upper teeth with downward strokes, the lower teeth with upward strokes; (2) brush chewing surfaces with a scrubbing stroke; (3) brush each area at least 10 times, including surfaces next to the tongue as well as those next to the cheek; (4) brush the teeth of each jaw separately.

Mouthwashes have been extensively advertised but are of doubtful value. Medicated mouthwashes should be used only on the recommendation of a dentist.

Another factor in dental health is a sensible diet. It is particularly important to reduce the consumption of carbohydrates, particularly sweets. Carbohydrates are essential in the diet to provide the energy necessary for muscular activity and for other functions of the body. However, in some countries the consumption of sugar has increased far beyond the normal needs of the diet. In the United States, for example, the consumption of sugar has increased from an average of five kilograms per person per year in 1830 to about 42 kilograms per person per year in the 1980's.

A reduction in the consumption of sugar will result in an appreciable decrease in the number of dental-caries cases. The frequency with which sweets are eaten is an even more important determinant than the



Malocclusion is a common dental problem—one that can usually be treated successfully. Near right: X ray of a young boy with a serious "overbite." Far right: X ray showing the effect of three years' treatment. The teeth are now better aligned. Improved chewing, speech, and appearance result.

amount consumed. Continued and repeated acid attack is more dangerous to the teeth than occasional attack.

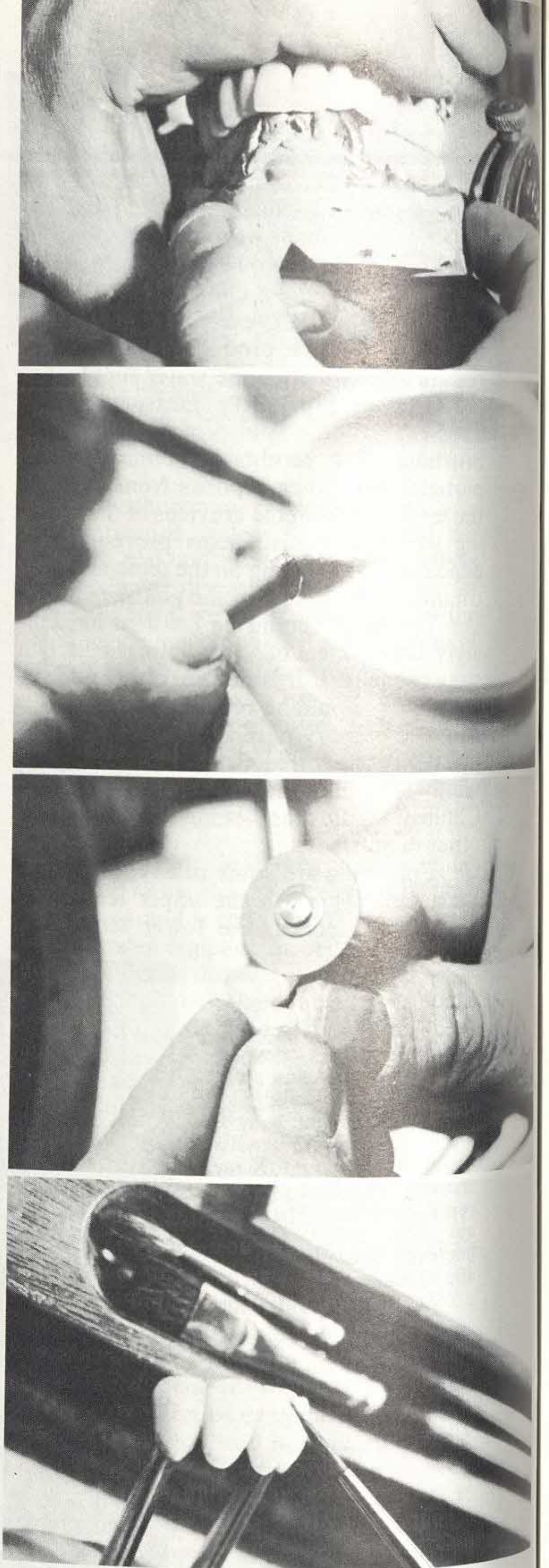
A well-balanced diet that is beneficial for general health will also be beneficial for the teeth during the period of development and later on. Supplements to the diet, in the form of added calcium, phosphorus, vitamins, or essential minerals, should be given only on the specific recommendation of a physician.

Preventive measures, such as proper toothbrushing, fluoridation of water or application of fluorides to the teeth, and reduction in the consumption of sweets, are very helpful. They cannot completely eliminate dental disorders, however. To control and prevent dental caries, periodontal diseases, and malocclusion, regular and frequent dental care is vital.

The child should pay his first visit to the dentist between the ages of two and a half and three. years, shortly after all the deciduous teeth have erupted. Early and frequent visits enable the dentist to detect the first symptoms of dental disease and irregularities in the growth pattern. Defects can then be corrected with a minimum of discomfort. In general, visits should be made every six months.

ARTIFICIAL TEETH

When teeth are lost, the dentist can often replace them by various dental prosthetic devices. A prosthetic device is an artificial substitute for a missing body part. In constructing such devices, dentists take into consideration a number of factors: mouth cleanliness; prevention of excessive pressure on soft tissues; prevention of interference with muscles of the tongue and cheeks; equal distribution of chewing forces on the supporting teeth. The appearance of artificial teeth is also an important consideration. At one time people were rather proud of showy gold teeth. Nowa-



all photos, Universal/Lactona—a division of Warner-Lambert Company

Making an artificial tooth. Top: a plaster cast of the patient's jaw is used as a model in fitting the artificial tooth. Next: building and shaping the new tooth. Bottom: coloring the tooth to match the patients other teeth.

days, however, most people want their artificial teeth to look as natural as possible.

There are various kinds of dental prosthetic devices. When the crown of a tooth cannot be saved, an artificial crown of porcelain, or gold, or other material may be adjusted to the root. Fixed or removable bridgework is employed to replace missing teeth when some natural teeth remain in the mouth. *Fixed bridgework* cannot be removed from the mouth. In this case, the false teeth are anchored by means of inlays or crowns to adjoining teeth. *Removable bridgework* is held in place by metal clasps fastened around natural teeth.

When a large number of teeth must be replaced, a *partial denture*, or *partial plate*, may be used. The partial denture covers various areas of the gums and the palate, in addition to the gap where teeth are missing. In this type of prosthetic device, the artificial teeth, of baked porcelain or plastic, are set in a base of plastic.

If all the teeth of the upper or lower jaws have been lost, a *full denture*, or plate, is prepared. It consists of artificial teeth of porcelain or plastic set in a plastic base. The base of an upper plate rests on the upper gums and the palate. The base of a lower plate sits on the lower gums.

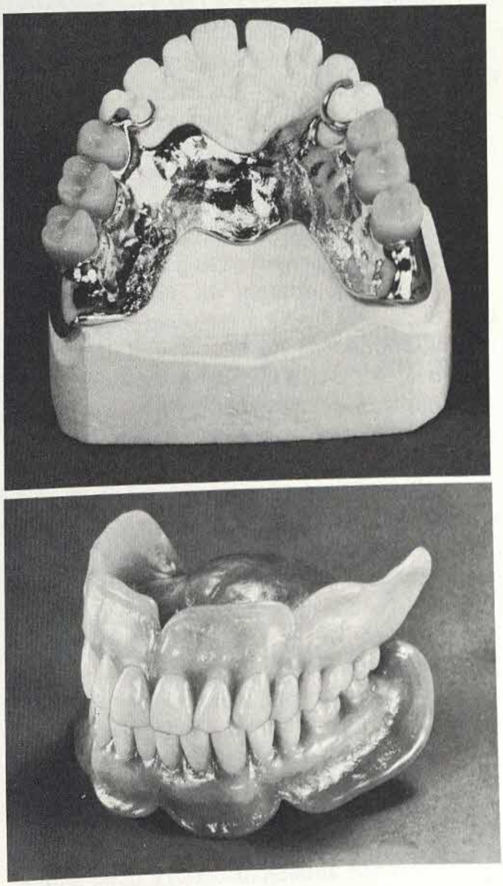
There is generally a certain amount of discomfort when a new dental plate is put into service, but the dentist can usually make adjustments that remedy the trouble. The wearer of a new denture may find it hard to speak and chew properly at first. Dentists recommend reading aloud for improving pronunciation in such cases. It may be necessary to modify certain normal eating habits in order to bring about improved mastication.

The ridges of the gums undergo certain normal changes over the years. Shrinking may occur, loosening the denture and causing a gradual change in the facial expression. Such a change may take place, even when dentures do not loosen, as the jaws come closer together following the shrinkage of the gums. Wrinkles or depressions form in the upper and lower lips; the lips become compressed and protrude. The chin moves forward and upward. The lip line straightens. Pronounced pouches develop on the sides of the lower jaw.

To avoid such facial changes, dentures should be relined or new ones should be constructed periodically, usually every three or four years. It is not advisable to try to reline dentures at home or to use denture adhesive powders.

RECENT DEVELOPMENTS IN DENTISTRY

Researchers have made important contributions to dentistry in recent years. Among these developments have been improved anesthetic agents, the use of antibiotics, the development of plastic filling materials, the design of new equipment, and



Top: a removable bridge for the upper teeth. The molars and second bicuspids on each side have been replaced, while the first bicuspids have been partially restored. Bottom: a full upper and lower denture, or plate.

the increased application of radioactive techniques to learn more about the teeth.

The most commonly used anesthetic agent in dentistry is the *local anesthetic,* which produces loss of feeling only in a specific area. The local anesthetic must be nontoxic, and it should produce a sufficiently deep anesthesia rapidly and for the desired duration of time. Many years ago procaine replaced the dangerous cocaine as the routine dental anesthetic agent. Today, often mixed with such drugs as tetracaine or propoxycaine, procaine is by far the most widely used local anesthetic. Three other drugs–butethamine, lidocaine hydrochloride, and metabutethamine–have also come into common use. Some of these agents are a boon to the small percentage of patients and dentists who are procaine-sensitive.

General anesthesia, or complete unconsciousness, is sometimes produced by gas–usually a combination of nitrous oxide, oxygen, and perhaps trichloroethylene. Sometimes unconsciousness is brought about by intravenous injection of a barbiturate–usually thiopental. Trichloroethylene is also used by itself to produce general analgesia, a state in which the patient is conscious but is insensitive to pain.

The development of antibiotics has had important applications in dentistry. If a patient about to have a dental operation has a history of valvular heart disease or rheumatic fever, he is given penicillin in order to prevent subacute bacterial endocarditis, a disease that sometimes proves fatal. Penicillin and other antibiotics, such as Aureomycin and the tetracyclines, are also used effectively in combating infections of the teeth and gums.

Another important development has been the use of plastic as a filling and sealant for teeth. Dentists have long sought an ideal filling material. Porcelain is a filling that blends in well, but it is fragile, and its use is limited largely to the front teeth where the factors of color and appearance are particularly important. Silver amalgam, a combination of silver, mercury, and other metals, is the most commonly used filling. It is serviceable enough but lacks the aesthetic appeal of porcelain. Gold is too conspicuous. Otherwise, it would be an ideal filling material, for when it is alloyed with certain other metals, it does not shrink or expand to any significant degree, and it also resists wear well.

Filling materials made of plastics known as acrylic resins have certain definite advantages. Such materials can be blended to produce almost any color or shade imaginable, and so can be made to match the person's natural teeth. Acrylic resins can also be molded into almost any shape. They are not brittle.

Plastic sealants are being used to wall off the biting surfaces of teeth from decay-causing bacteria. Studies have shown that children's back teeth sealed with a plastic remain almost totally decay-free.

Another simple technique employs an acrylic resin to reconstruct a broken front tooth, a common injury in children. Plastic is also used for total replacement of a missing front tooth. Here a plastic crown is bonded to the teeth on either side of the space.

New dental drills have been designed to overcome the discomfort caused by traditional rotary drills. Small waterpowered turbine drills have attained speeds of between 60,000 and 70,000 revolutions per minute. Air turbines that rotate at up to 300,000 revolutions per minute are now in common use. Research work has indicated that speeds of even 10,000 revolutions a minute practically eliminate the sensation of vibration that causes so much discomfort and even pain to patients when slower drills are used.

Radioactive isotopes have proved to be effective tools of research. They have added to our knowledge of tooth structure and dental disease and have led to improved methods of dental treatment. Deposits of radioactive calcium have been used to study the processes of tooth formation. Radioactive tracers of calcium chloride have tested the efficiency of certain techniques in placing dental fillings. More than 20 radioactive compounds have been used in dental research.

Merck Sharpe & Dohme

This child is receiving his immunizations against rubella, poliomyelitis, diphtheria, and other diseases, many of which were once serious problems throughout the world.

DEFENSES OF THE BODY

by W. W. Bauer

The human body, moving over a long span of life, through a world filled with hazards, possesses a remarkable system of defenses against attacks from without—against accidents (or other violence) and disease. It has an outer wall, many internal defenses, and a highly ingenious regulatory system. A U.S. physiologist, Dr. Walter B. Cannon, has described this elaborate series of defenses as "the wisdom of the body."

WARNING SIGNALS

The organs of perception provide warning of violence, due either to accident or to intentional attack. The eye can perceive, or the ear detect, the approach of danger. Man's sense of smell is less acute than that of many animals, but it is keen enough to help ward off danger of injury from fire or chemical fumes. Skin sensation is useful in detecting contacts with crawling insects and other animals that may have a dangerous bite and in warning of excessive heat or cold. It also helps us to determine the texture of solid objects or the character of fluids with which we make contact.

Closely allied to the senses of perception is the action of the nervous system. A warning signal received through the eye, the ear, the nose, or the skin is transmitted to the brain, which then directs appropriate action. If there is plenty of time, this may be a conscious action. You may be driving a car and see a traffic jam in the next block. You slow up, look the situation over as you approach, and then decide what to do next. But if the driver ahead of you suddenly puts on the brakes, you do the same before you have time to size up the situation. This is called *reflex action*. A reflex action takes place when you duck without thinking as a snowball is thrown at your head. In fact, the chances are that you will duck even if you know there is a heavy sheet of unbreakable glass between you and the oncoming object. Reflex action is at work, too, when you jerk your hand away upon touching a hot stove.

REFLEX ACTIONS

This is how reflexes work. In the skin there are tiny organs called receptors. There is a different one for each sensation: pain, heat, cold, pressure, texture, and so on. From these, the nerve fibers go through various nerve trunks to a nerve center, or ganglion, one of a chain which is just outside the spine in the abdominal, chest, and neck regions and in various places in the head. Here the impulse is delivered to other nerve fibers, in much the same manner as a telephone relay carries the voice from station to station, and the message is conveyed to the brain. Action impulses then originate in the brain. They are transmitted to a nerve center in the spinal cord and from there, by other nerve fibers, to muscles that bring appropriate sense receptors, such as the eyes, nose, or fingers, into play. Thus, we look at, or smell, or feel the object that has stimulated our skin receptors and learn what it is like.

But if there is an emergency, the whole action is short-circuited. We touch a hot stove, and the pain sensation flashes to the spinal-cord relay station. Here it is intercepted and transmitted to the appropriate nerve fibers bringing about action. These at once impel the appropriate muscles to get the hot contact broken without delay. The interception saves the longer time it would take for the danger signal to reach the brain, and there to be transferred through a number of nerve paths and connections to the cells on the upper surface of the brain that ordinarily control voluntary actions.

PAIN IS A SAFEGUARD

Pain sensations occur in many parts of the body other than the skin and are manifested in different ways. The brain substance feels no pain, but the covering membranes do. The intestines are insensitive to cutting, but react painfully to twisting, pulling, or distention with gas. Pains may be steady or intermittent, sharp or dull, shooting or burning. Pain is usually regarded as something to be avoided. Actually it is a safeguard. It is a signal that something is wrong. Properly interpreted and acted upon, it is a safety device, a protective function.

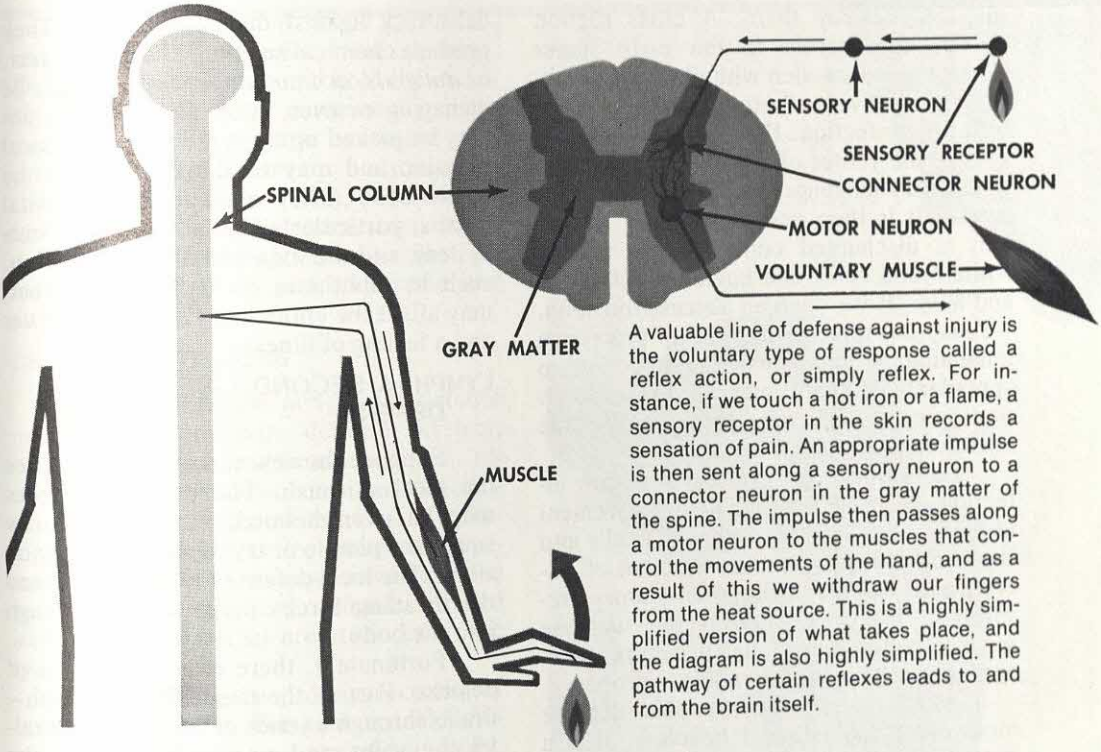
Closely related to pain are other uncomfortable sensations such as itching, nausea, dizziness, and faintness, which indicate that some function is disturbed and needs attention. These sensations should be heeded, particularly if they are severe, if they tend to return at frequent intervals, or if they are present for more than a few hours.

Two substances that play a role in a person's perception of pain are endorphins and enkephalins. These chemicals, which are produced in the brain, are "natural morphins" that are released in response to pain. Their release is also stimulated by certain drugs and by acupuncture. This may account for how the latter procedure can reduce perceived pain.

Drugs such as Valium, opium, and Librium work by attaching to specific receptor cells in the nervous system and blocking the reception of pain without affecting other sensations. In the late 1970's, it was discovered that the natural brain-produced substances bind more tightly to receptor cells than the synthetic chemicals do. Thus, while pain is a signal that something is wrong, the brain also produces substances that can mediate the intensity of the pain.

FIRST LINE OF DEFENSE

Diseases that attack the body from without are met with what can be called defense in depth. When one defense is breached, another stands ready to take over. The first line consists of the skin and the mucous membranes of the body. Attacking germs do not really get inside the body until they have penetrated either the skin that covers it or the mucous membrane that lines it. The digestive and breathing systems, commonly considered to be inside



A valuable line of defense against injury is the voluntary type of response called a reflex action, or simply reflex. For instance, if we touch a hot iron or a flame, a sensory receptor in the skin records a sensation of pain. An appropriate impulse is then sent along a sensory neuron to a connector neuron in the gray matter of the spine. The impulse then passes along a motor neuron to the muscles that control the movements of the hand, and as a result of this we withdraw our fingers from the heat source. This is a highly simplified version of what takes place, and the diagram is also highly simplified. The pathway of certain reflexes leads to and from the brain itself.

us, have parts exposed to the outside. They are covered with mucous membrane, which resists penetration.

The defenses supplied by the skin are of several different kinds. A natural barrier is provided by the outer layers of dead, flattened cells. They may be scuffed off without damage to the body and without pain. The oiliness of the skin, derived from the sebaceous glands, makes it waterproof and helps to prevent germ invasion. The blood vessels in the skin rush blood to the menaced area and thus bring to bear forces that fight germ progress.

Mucous membranes afford protection through the chemical composition of their secretions. The slightly acid saliva in the mouth and the more strongly acid stomach secretions both help to keep bacteria at a minimum. In the nose, the membranes have tiny cilia, or hairlike structures, which have a rhythmic waving motion toward the nostrils, thus moving secretion, dust, and germs outward.

INVASION BY INFECTIOUS AGENTS

If the skin is broken, the way is prepared for the entry of infection. Small breaks heal quickly, first being sealed against invasion by the clotted blood, which not only prevents hemorrhage but also constitutes a defense against infection. If, however, infection has been introduced at the time of the injury, there may be a small center of inflammation around the affected area. It will become reddened. There will be pain or throbbing and heat. Perhaps abscesses will form. A typical abscess on the surface of the body is a *boil*.

This is what happens when the infection sets in. More blood is rushed to the point of entry, accounting for the increase in local temperature, and the blood brings with it more white cells. These do not remain inside the blood vessels, but ooze through the thin and easily permeated capillary walls into the tissues, where they meet the invading organisms and attempt to engulf and destroy them. A cross section through an abscess in the early stages shows tissues swollen with blood and making a protective wall around the site of entry of the infection. If the infection is held at bay, the center of the abscess liquefies. In ordinary language we say it "comes to a head." It is then ready to open. The pus that is discharged contains fluid serum, white blood cells, and bacteria, both dead and alive. If we open an abscess too soon, we may cut through the wall of protective inflammation and cause the infection to spread into deeper tissues or into the blood. Squeezing a pimple may produce the same unfortunate effects.

The sequence of events that follow infection–increased blood flow; movement of fluids, blood protein, and white cells into the damaged area; and destruction of microbes–is called the *inflammatory response*. It is a *nonspecific defense mechanism,* meaning that it occurs in response to all kinds of invading microbes.

Interferon is a nonspecific defense mechanism against viral infection. It is a protein that inhibits viral replication and can be produced by several different cell types in the body in response to viral infection of the particular cell. Interferon synthesis begins within hours of the onset of viral infection, and, unlike antibodies, interferon can enter and function inside infected cells to prevent further multiplication of the virus. Physicians may be able to administer interferon to patients suffering from viral illnesses to enhance their resistance.

The invasion of the body by infectious agents–bacteria, viruses, molds–has been likened to war. There are local skirmishes at the points of attack, followed later by generalized battles. In this war, the cells and the chemical constituents of the blood, tissue cells, and body fluids represent the defending forces against the invaders. The white cells may be compared to the infantry, which does the hand-to-hand fighting and which mops up after the action. Either the enemy is repelled or the defenders are overwhelmed.

The invading bacteria direct a chemical attack against the body tissues. They produce chemical substances, called *toxins,* or *antigens,* or *immunogens,* which may be damaging or even fatal. These substances may be picked up from the site of the local invasion and may be carried through the whole body. They may do harm to vital organs, particularly the heart, the nervous system, and the kidneys. A local infection, such as diphtheria or septic sore throat, may affect the entire body, producing fever and a feeling of illness.

LYMPH–A SECOND LINE OF DEFENSE

Suppose, however, that the body loses the local skirmish. The defending forces may be overwhelmed, or a person may squeeze a pimple or try amateur surgery on a boil. The local defenses are bypassed, and the invading forces make a breakthrough into the body.

Fortunately, there is a second line of defense. Part of the tissue fluids–lymph–drains through a series of vessels that parallel the veins and eventually convey the lymph into two large vessels. These lymph vessels lead through collections of spongy tissue known as *lymph nodes,* which constitute traps for infection. Lymph nodes are strategically placed at circulation bottlenecks, which correspond to the easily defended posts. The tissue fluids from the hand, for example, pass through lymph nodes near the elbow, and again in the armpit; those from the foot, through nodes near the knee and in the groin. These nodes are filled with a special type of white blood cells–the *lymphocytes*. They may break down in the process of handling heavy infections and form abscesses, but they protect the main body structure and the vital organs. An infection that has overcome local defenses may often be traced by angry red lines running from the point of injury up the arm or leg. These are the inflamed lymph vessels. There are systems of lymph nodes and drainage vessels that serve the internal organs in the same manner as the superficial nodes serve the extremities.

In certain instances of tuberculosis, the attack upon the lymph nodes is less violent but more persistent. If all goes well, nodules, called *tubercles,* will develop. These nodules will trap and hold the invading bacilli, sometimes permanently. Ultimately, they will become encrusted with calcium deposits. If later the body is weakened by fatigue, malnutrition, or further infection, the walls of the nodules may break down, releasing the imprisoned bacilli. This may take place many years after the first attack.

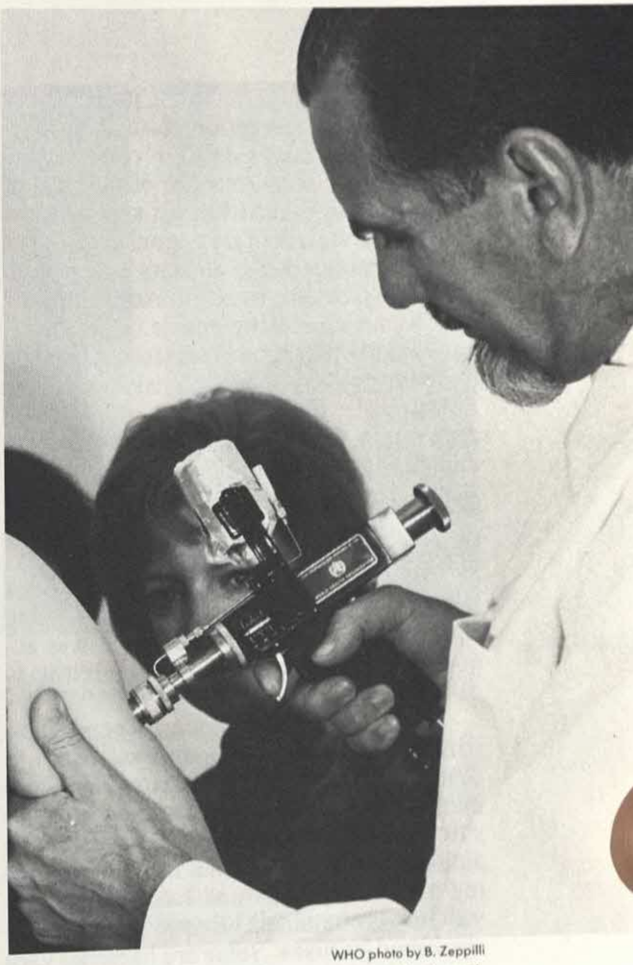
CHEMICAL DEFENDERS

In contrast to the nonspecific defense mechanisms, another defense system, called *specific immune mechanisms,* responds to foreign substances that the body previously has been exposed to. These foreign substances are called *antigens.* Reaction to these antigens involves the production of chemical defenders called *antibodies.* Antibodies are produced by the lymph tissue.

An antibody is a protein secreted by cells called B cells. For each specific antigen, the body produces a specific antibody. The antibody then combines with the antigen in a lock-and-key type arrangement. This combination of antigen and antibody can have two results. First, antibodies directly neutralize some viruses or bacterial toxins. Second, the antigen-antibody complex triggers an inflammatory response by interacting with a series of blood plasma proteins called *complements.* The antigen-antibody complex activates these complements and thereby starts a sequence of events ultimately resulting in *phagocytosis,* or the engulfment of the invading organism by phagocytes such as white blood cells.

In addition to antibodies secreted by B cells, the specific immune system also involves a population of lymphocytes called *T cells.* There are three main subsets of T cells, each described by its functions. *Cytotoxic T cells* eliminate virus-infected cells. *Suppressor T cells* have a regulatory effect on the immune system. *Helper T cells* assist antibodies and antibody-producing B cells.

T cells become sensitized to a specific antigen once they are exposed to that antigen. When the T cells later encounter the same antigen, they combine with it. B cells are located in the lymphoid organs and secrete antibodies that interact with antigens. In contrast, T cells travel to the invasion site and combine with antigens.



WHO photo by B. Zeppilli

Smallpox vaccinations are given to people traveling to regions where the disease is still known to occur—very few regions now, thanks to highly successful public health and vaccination programs at work around the world.

A recently discovered health problem associated with a breakdown of the specific immune system has received widespread public attention. *Acquired Immune Deficiency Syndrome* (AIDS) patients have normal or elevated levels of B cells and antibodies. The number of suppressor T cells seems unaffected, but the number of helper T cells and cytotoxic T cells is low.

Overall, the immune system is held back from attacking foreign organisms. As a result, many victims of AIDS develop several diseases, including a cancer of the skin or internal organs called Kaposi's sarcoma or an unusual variety of pneumonia.

At present, AIDS appears to be contagious—passed on by "intimate contact" such as a shared drug needle or sexual intercourse. Epidemiological studies indicate that four groups are at high risk of catching AIDS—male homosexuals, intravenous drug users, Haitian-born residents of the United States, and hemophiliacs.

IMMUNIZATION

There are various kinds of immunity, or protection from disease. If it occurs as a result of having a disease and overcoming it, it is called *natural* immunity. If it is acquired by a man-made procedure, it is called *artificial* immunity.

Types of immunity that depend upon stimulation of the body's own defenses are described as types of *active immunity*. Such immunity may last for many years. The substances used to provide lasting immunization are antigens. Some, used in protecting against smallpox and rabies, are virus vaccines, containing living, but greatly weakened, viruses. Some are bacterial vaccines—killed bacteria in suspension. Some, called toxoids, are greatly weakened toxins. All have the property of stimulating body tissues to form antibodies against the disease-producing agent. All provide active, artificial immunity.

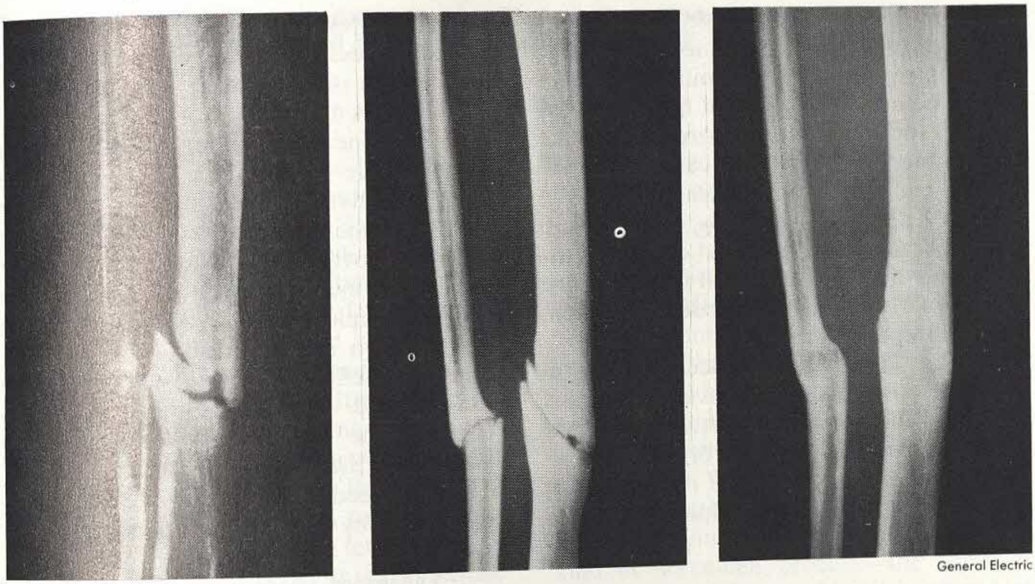
In another type of immunity—termed *passive immunity*—the body's defensive mechanisms are not stimulated. Rather, the chemical defenders—the antitoxins—are administered directly into the body. Suppose that a child exposed to serious disease has not had previous immunization. Then, as in diphtheria, we may give the child a preventive injection of diphtheria *antitoxin*. Passive immunity is only temporary.

Some persons find it hard to distinguish among vaccines, toxoids, serums, and antitoxins. A *vaccine* is prepared from a virus or a culture of bacteria. A *toxoid* is prepared from the liquid culture medium in which bacteria or viruses have grown and produced their toxins. A *serum* is the liquid portion of human or animal blood that contains immunizing substances. An *antitoxin* is the purified immunizing agent derived from a serum. Use of serums is decreasing because of the danger that they may trigger allergic attacks.

Merck Sharp & Dohme

The practice of vaccination started with Edward Jenner, here shown vaccinating a baby against smallpox.

Man has taken advantage of the slowly unfolding knowledge of natural immunity provided after recovery from disease. An English country doctor, Edward Jenner, led the way in 1798 with his famous *Inquiry into the Cause and Effects of the Variolae Vaccinae (cowpox)*. In this monograph he showed how he could prevent smallpox by *vaccination*—that is, by inoculation of the patient with cowpox. Nowadays the practice of vaccination is universal, and smallpox exists only in very isolated regions where vaccination is neglected. The same basic principle, with variations in detail, is used in immunizing children against diphtheria, whooping cough, tetanus, polio, flu, and rubella. In areas where water supplies may be contaminated, typhoid vaccination may be advised. Persons traveling into cer-



General Electric

In some cases, there is complete recovery from disease or injury. For example, bone heals well and full function is generally restored. We show three stages in the healing of the lower leg bones.

tain areas, particularly in the tropics, Asia, and the Middle East, may also be advised or required to be vaccinated against cholera, typhus, yellow fever, or other diseases occurring in those areas and for which there is available protection.

Certain diseases can be warded off by individual immunization, but not on a mass basis. For example, until recently measles was preventable only by immunizing with gamma globulin, or GG. Measles was so prevalent, however, and the supply of GG so limited, that mass advance immunization was impracticable, even if the GG measles immunity were lasting, instead of being limited to a few weeks. Now, a practical measles vaccine for mass immunization is available.

GENERAL INFECTIONS

Some infections are so massive or so violent that they immediately overwhelm all local and secondary resistance and enter the blood stream. In some cases infection is introduced directly into the blood. Unless there has been previous immunization, such general infections, as they are called, are often serious and sometimes fatal. They include rheumatic fever, typhoid fever, and chronic infection of the heart valves by a streptococcus. They may be overcome by the body's own immunity mechanism, through the gradual development of antibodies. The course of the disease indicates the struggle between infection and resistance. The result is recovery, death, or chronic disease.

RECOVERY

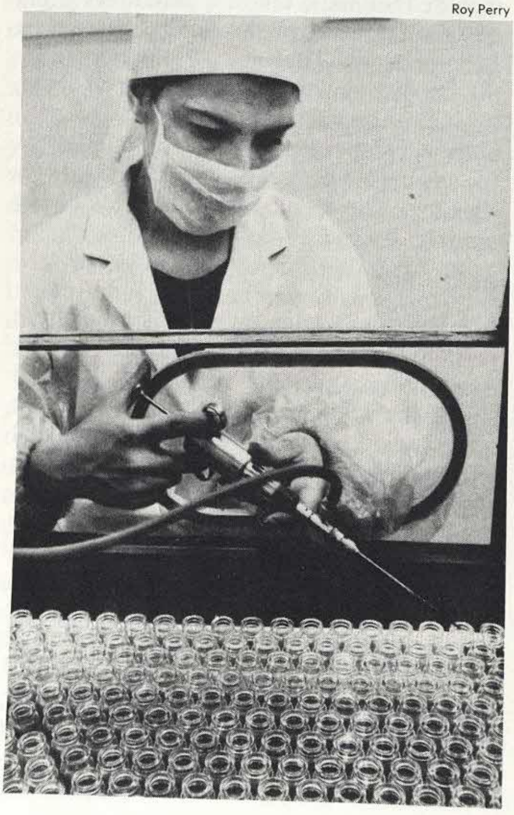
Even when the patient has recovered, certain organs or tissues may have been more or less seriously damaged. In such cases, the body may continue to function quite well, as long as there are no unusual stresses. Scarlet fever, for example, before modern drug treatment, frequently did serious injury to the kidneys, destroying some cells and damaging others. Under proper treatment, recovery would take place in some instances. If the injury to cells had not been too great, they would recover and resume their function. The cells which had been killed would be partially replaced by other cells of similar character or by fibrous scar tissue.

If the end result of the healing process, following disease, injury, or surgical removal, leaves too much scar tissue and too little cell replacement, there is limitation of function. There is a final line of defense, even against such limitation. There is so much tissue reserve that in many cases there will be enough functioning tissue to meet the ordinary needs of the body. As a result, many persons with damaged organs or tissues may live long and well by exercising due care and remaining under competent medical supervision.

Many tissues are replaceable after injury. Muscles, skin, and even bone heal well, and full function is restored except in very severe injuries. Vital organs such as the heart have a high rate of recovery after serious injury, as from diphtheria toxin, rheumatic fever, or even a heart attack. There is much more kidney and liver substance than is required for ordinary living. The mucous membranes of the lungs, stomach, intestines, and other internal organs are still able to carry on after they have been extensively damaged.

Once a new vaccine against a disease is developed, it is thoroughly tested and then quickly made available throughout the world. Here a technician fills vials with a new vaccine.

Roy Perry



To some extent, certain organs may even take over the activity of others that have been impaired. The stomach can be almost completely removed, and digestion still goes on in the intestines with hardly diminished efficiency, if a few eating habits are modified. Removal or failure of glands can now be remedied by supplying the hormones they would normally secrete. Thyroxin feeding by mouth and insulin replacement by injection are prominent examples.

The more specialized tissues are not replaceable by healing, once they have been destroyed. When the nerve of hearing is gone, that function is lost forever. Vision is lost when the optic nerve is destroyed. When cells of special sense nerves and of the brain and spinal cord are killed, they are not replaced by other nerve cells but by scar tissue. Thus when a brain area concerned with a certain function, such as muscle control in the hand or the foot, is destroyed, the hand or foot will be paralyzed, unless other muscles can take the place of the lost muscle. It is true that sometimes recovery or at least partial recovery may occur after a brain injury, but this is because the nerve cells have not been destroyed, but only injured.

Many nerve cells have long filaments carrying impulses to a distant point or bringing them from that point. If such a filament is cut but the cell remains intact, function will return when a new filament has grown along the path of the injured one.

In the healing process involving the less specialized tissues, new cells are formed only to the extent that the tissue is made whole again and resumes its function. In the normal individual, regrowth and scarring seldom get out of control. In a few instances a scar may form a thick structure called a *keloid*, which can usually be corrected by plastic surgery.

THE NERVOUS SYSTEM

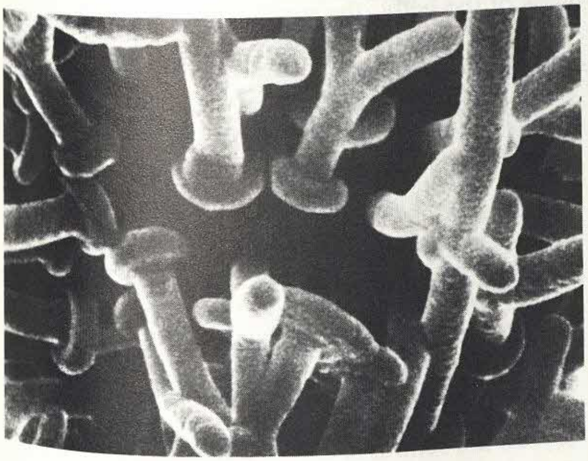
by J. Fremont Bateman

Of all the systems of the human body, the nervous system is the most highly developed and most complex. It keeps us in contact with our environment, tells us what we see, and distinguishes between the various sounds that we hear. It informs us when we are tired and need rest or sleep, when we are hungry and need food, when we are too hot or too cold. It regulates the functions of the other systems of the body, usually independently of our will. It keeps us in equilibrium. It controls the muscles of our arms, hands, and fingers so that we can button a garment, or write a letter, or use a knife and fork at the table. It is responsible for our thinking, our behavior, our feelings and attitudes, our likes and dislikes.

We can think of the nervous system as a communication network strung throughout the body. The "wires" of this system—the *nerve fibers*—carry "messages." These are in the form of impulses from sensitive areas on the surface of the body or inside it to the central nervous system. The central nervous system is made up of the *brain* and *spinal cord*. From the central nervous system the nerve fibers transmit impulses to muscles and glands.

Photo of nerve fibers and knobs of a sea snail taken through a scanning electron microscope. The synaptic knobs pass impulses from one nerve cell to another in the network.

UPI



THE NERVE CELL, OR NEURON

The basic unit of the nervous system is the nerve cell, or *neuron*. It consists of a *cell body*, containing a *nucleus*, and a number of fine, threadlike processes extending from the cell body. There are two kinds of processes: *dendrites* and *axons*.

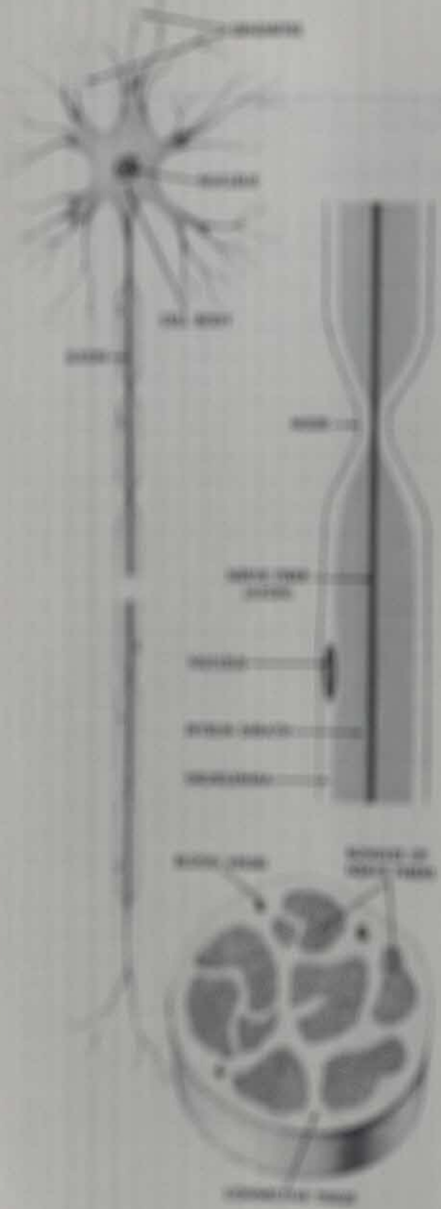
Each nerve cell generally has a number of dendrites. These are short and often branch repeatedly so that they form a sort of bush around the cell body. The other kind of nerve-cell process—the axon—is usually long and very thin. It is often less than 0.01 millimeter in diameter. Each cell has only one axon. This may extend for a distance of only a few centimeters, or it may run all the way from the spinal cord to the tip of a toe or finger. Certain axons give off a few small branches near the cell body.

In the central, or *cerebrospinal*, nervous system, all the cell bodies are gathered together in the brain and the spinal cord. The cell bodies form the gray matter of these two organs.

The axon of each neuron forms a single *nerve fiber*. Certain fibers connect various neurons with one another. The individual cells make contact through their processes. The axon of one cell branches toward its end, and these branches are directed toward the dendrites of another cell. The junction between the axon of one nerve cell and the dendrites of another is called the *synapse*. A message that has traveled along the axon of one cell crosses the junction to the dendrites of another cell and then is relayed by the axon of the second cell to a third cell.

NERVE FIBERS

Nerve fibers that transmit impulses from various parts of the body to the brain or spinal cord are called *afferent fibers* (from the Latin *afferre*, meaning "to carry to or in"), or *sensory fibers*. The fibers



At the left, above, is shown a typical nerve cell, or neuron, consisting of a cell body, dendrites, and axon. [illegible] At the right is a close-up of an axon, showing the myelin sheath, the neurilemma and a node, representing a portion of the axon without a myelin sheath. The lower right-hand drawing shows a cross section of a nerve, made up of bundles of nerve fibers, connective tissue and blood vessels.

transmitting impulses from the brain or spinal cord to various body structures are known as *efferent* (from *efferre*, meaning "to carry out or away"), or *motor, fibers.*

Bundles of fibers (that is, axons), coming from various nerve-cell bodies, lead from the brain and spinal cord. They make up what we call *nerves*, and they extend to various parts of the body. There is two-way communication along the nerves connected with the spine. These nerves bear both afferent and efferent fibers. Some of the nerves leading from the brain also have such mixed fibers. Others have only afferent fibers or efferent fibers.

NERVE MEMBRANES

Many of the nerve fibers within the spinal cord and brain are covered by a layer of white tissue called the *myelin sheath*. These sheaths help to keep the nerve fibers electrically charged. In other words, they act as insulators.

In the nerve fibers outside the central nervous system the myelin sheath is not continuous, but is interrupted at regular intervals. It produces the effect not of a cylinder but of a string of extremely long and thin sausages with short lengths of cord between them. The nonmyelinated portions are called the *nodes of Ranvier.*

Between the myelin sheath and the nerve fiber there is a fluid membrane which conducts the nerve impulses.

In the nerve fibers that come from the brain and spinal cord and that lead to other parts of the body, the myelin sheath is enclosed in turn by a thin, semitransparent protective membrane called the *neurilemma*. As it approaches its end, the nerve fiber loses first its myelin covering and then its neurilemma. At its end, the axon almost always divides into two or more terminal branches. Each of these branches breaks up into numerous terminal twigs. At the tips of the nerves, therefore, we have a group of naked fibers, which make contact with the same organs, muscles, or glands.

When the nerve fibers within the brain and spinal cord are cut, they can never be restored. But if the fibers that extend out beyond the central nervous system are sevpair, regeneration often takes place. This is a fascinating process. The portion of the fiber that has been cut off from the cell body disintegrates until only the neurilemma is left, as an empty tube. The rest of the fiber, connected with the cell body, remains intact. It begins to send out processes which enter the empty sheath of neurilemma and make their way through its entire length.

STIMULATING A NERVE

Sometimes nerves are directly stimulated by something which disturbs their conductive membrane. This happens, for example, when you receive a crack on your funny bone or when electric current is applied to the skin overlying a nerve trunk or a thick bundle of fibers. Generally, however, stimuli act upon various receptor organs, such as those of sight, hearing, smell, and taste. Some of the receptors respond to stimuli from the outer world. Others respond to stimuli within the body itself.

When a sense receptor, such as that of touch, is subjected to a steady stimulus, the impulses that travel along the appropriate nerve fibers follow one another very closely and may force themselves upon our consciousness. This high frequency, however, falls off if the stimulus continues unchanged. In time, we may no longer be aware of any sensation. For example, when you first put on shoes and socks after remaining barefoot for several hours, as when you spend an afternoon at the beach, the steady pressure of the footgear will bring about a rapid sequence of impulses. You will distinctly feel the pressure. As the stimulus is maintained, the impulses will become fewer and fewer and you will no longer be conscious of any pressure. The conduction system has been stabilized.

RESPONSE – ALL OR NONE

The speed of the nerve impulse depends upon the thickness of the nerve fibers: the thicker the fiber, the more rapid the impulse. In the large motor fibers of mammals, the rate is from 80 to 120 meters per second. The sensory fibers of the skin are thinner and impulses travel along these fibers slowly.

An impulse set up by a very strong stimulus does not differ at all from an impulse resulting from a very weak stimulus. Both travel at the same rate and one is just as strong as the other. However, even a weak stimulus must have a certain intensity if an impulse is to occur. This is called the *all-or-none principle.*

It is true that a strong stimulus may bring about a stronger muscular response than a weaker stimulus. This does not seem to contradict the all-or-none principle. The fact is that a nerve consists of many fibers. A weak stimulus excites only a part of these fibers, while a strong stimulus may excite them all.

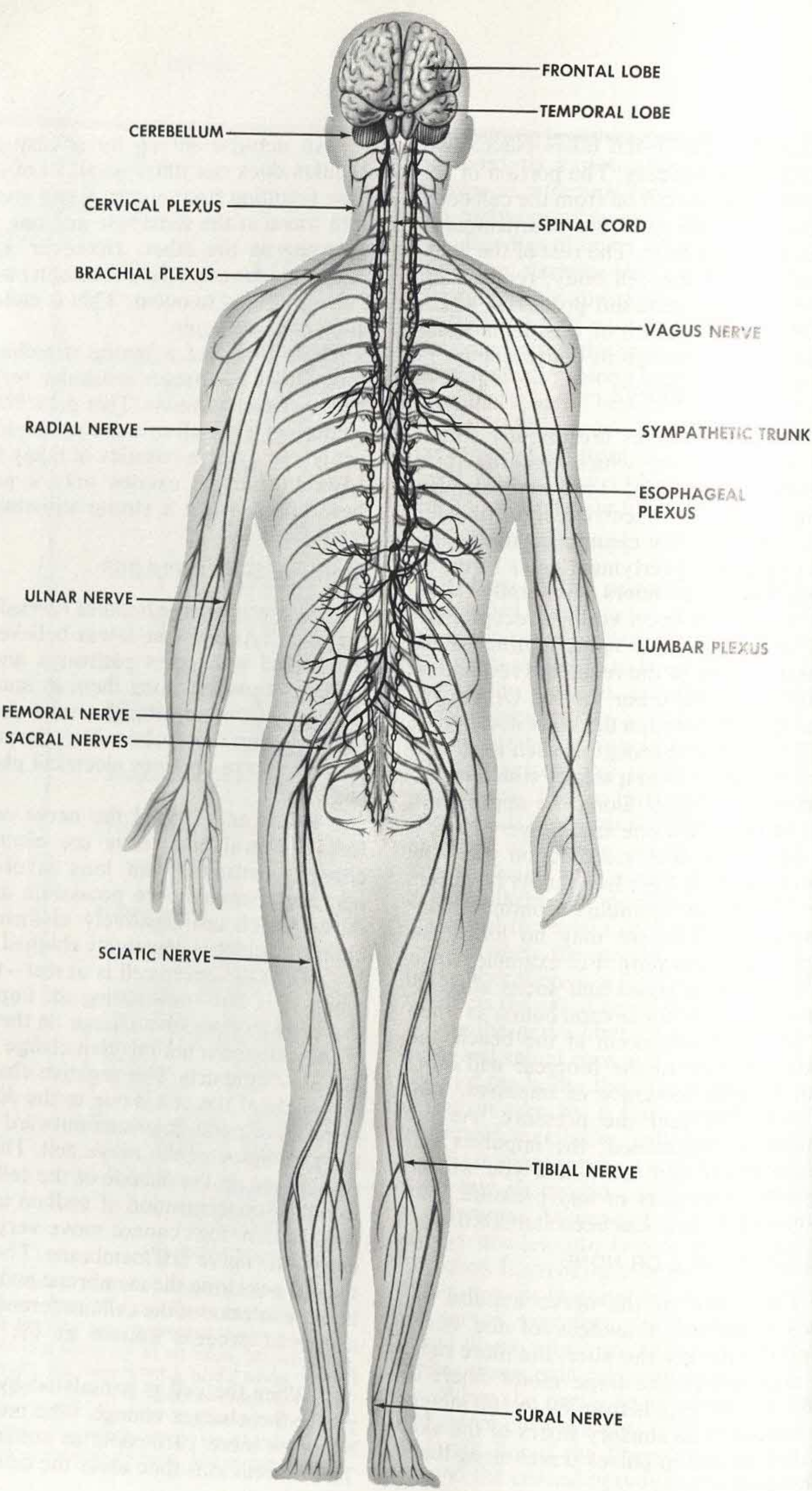
TRANSMITTING IMPULSES

How is the nerve impulse carried along the fibers? At one time it was believed that the nerves were mere pathways and that impulses traveled along them in much the same way as water through a tube. According to modern theory, however, the passage of the impulse involves electrical phenomena.

Inside and around the nerve cell are found several ions. Ions are electrically charged particles. The ions involved in nerve transmission are potassium and sodium, which are positively charged, and chloride, which is negatively charged.

When the nerve cell is at rest—that is, when it is not transmitting an impulse—there is a net negative charge on the inside of the cell and a net positive charge on the outside of the cell. The negative charge on the inside of the cell is due to the diffusion of positive potassium ions outward across the membrane of the nerve cell. The positive charge on the outside of the cell is due to a high concentration of sodium ions. At rest, sodium ions cannot move very freely across the nerve cell membrane. Those few that do penetrate the membrane and diffuse into the interior of the cell are forced out by a special process known as the sodium pump.

When the cell is stimulated by an impulse, the charges change. The membrane becomes more permeable to sodium ions. The sodium ions then enter the cell. Along


FRONTAL LOBE
TEMPORAL LOBE
CEREBELLUM
CERVICAL PLEXUS
SPINAL CORD
BRACHIAL PLEXUS
VAGUS NERVE
RADIAL NERVE
SYMPATHETIC TRUNK
ESOPHAGEAL PLEXUS
ULNAR NERVE
LUMBAR PLEXUS
FEMORAL NERVE
SACRAL NERVES
SCIATIC NERVE
TIBIAL NERVE
SURAL NERVE

ing the net charge of the cell interior to positive. The great influx of sodium ions disrupts the sodium pump momentarily. As more and more sodium ions enter the cell, the charge on the outside of the cell changes to negative. This process occurs stepwise throughout the length of an axon in nonmyelinated cells. In this way the nerve impulse travels from the nerve cell body down the length of the axon to its end.

In myelinated cells, the impulse is transmitted in leaps from one node of Ranvier to the next. This mode of impulse transmission is called *saltatory propagation*. It is usually much faster than the stepwise process.

The axon carrying the impulse ends in several *terminal fibrils*. At the ends of these fibrils, or knobs, there are special structures called *synaptic vesicles*. These vesicles contain a substance that transmits the impulse from the end of the axon across the synapse to another nerve cell. Acetylcholine is a common transmitter substance.

The acetylcholine flows into the gap, or *synaptic cleft*, between the two nerve cells. It then becomes bound to special receptor sites on dendrites of the second nerve cell. This triggers changes in the dendrite membrane and the processes by which a nerve impulse is transmitted are again started. The impulse has been transmitted from one nerve cell to another.

REFLEXES AND REFLEX ARCS

In some cases, when receptor organs are stimulated, there is an involuntary muscular contraction or glandular secretion, known as a *reflex*. The impulse that results from such stimulation is carried to the central nervous system—to the spinal cord or to the brain by way of the spinal cord—and is transmitted to a muscle or a gland. The complete path of the impulse is called the *reflex arc*.

In its simplest form a reflex arc consists of three parts. (1) The *afferent limb* consists of the receptor organ (the eye, say, or the ear or the skin) that gives rise to the impulse and the neuron whose processes carry the impulse to the central nervous system. (2) The *reflex center*, in the gray matter of the central nervous system, is made up of the central process (axon) of the afferent neuron and its junction with the cell body of the efferent neuron. (3) The *efferent limb* consists of the efferent neuron and its processes, which carry impulses from the central nervous system to a muscle or gland. Generally, other neurons are interposed between the afferent and efferent neurons. Some reflex arcs are very complex, involving a number of different muscles.

Conduction over complete reflex arcs differs in several respects from conduction along single nerve fibers, since a reflex arc is made up of a number of nerve cells connected end to end. For one thing, the all-or-none principle does not apply here, for the stronger the stimulus, the more vigorous may be the response. Reflex conduction over the entire arc is slower than that in single nerve fibers. This is because the impulses passing around a complete reflex arc are not only conducted by nerve fibers but must also pass through a smaller or larger number of cell bodies and synapses. The electrical and chemical conductions at the synapses are very different from those along a continuous fiber.

There are various kinds of reflexes. The knee jerk, a short twitch of the knee extensor muscle, is caused when one taps the tendon at the kneecap. There is the biceps jerk, produced when the biceps tendon is tapped. There is *muscle tonus*, which is the continuous partial contraction of the muscles that maintain good posture.

Certain reflexes represent inherited connections and characteristics and do not depend upon our personal experience. They are called *unconditioned*. Others, known as *conditioned* reflexes, are based, in part at least, upon previous experience. The following example will show the difference between the two kinds of reflexes.

When food enters the mouth, it stimulates various nerve fibers and leads to a plentiful secretion of saliva from the salivary glands. This secretion represents an unconditioned reflex. There are times, however, when the secretion of saliva is a conditioned reflex. Before we actually put food in our mouth, we see it and smell it. We come to associate its appearance and odor with its taste. As a result, when we see and smell food that we like, even though we do not actually taste it, saliva is secreted as before, and our mouths will water. In this case, the secretion represents a conditioned reflex. Conditioned reflexes vary in different individuals.

THE CENTRAL NERVOUS SYSTEM

The brain and the spinal cord, as we have seen, make up the central nervous system. All stimuli coming to receptors from the surface or inside the body are registered here, and all the responses that bring about movement or secretion originate here. Both the brain and the spinal cord are protected by bony structures: the brain by the skull, the spinal cord by the spinal column, or backbone. They are also protected by certain membranes, called the *meninges,* which we shall describe later.

THE BRAIN—LARGE AND COMPLEX

The brain is the largest and most complex part of the entire nervous system. Its average weight is about 1,360 grams in man and 1,250 grams in woman. The weight of the brain does not necessarily indicate the state of one's mental development. Some eminent persons have had brains weighing less than the average. A person with a small head but well-developed brain cells may possess far more intelligence than a person with a large head and a heavy brain.

The brain consists of a *brainstem* which is a continuation of the spinal cord, and certain structures, such as the *cerebrum* and the *cerebellum,* that have developed from the brainstem. The brainstem is divided into three parts: the hindbrain, the midbrain, and the forebrain. A narrow canal runs within the stem. It is filled with a liquid called *cerebrospinal fluid.* The brainstem does not differ greatly in the various vertebrates, including man. What distinguishes man particularly from all other vertebrates is the tremendous development of the cerebrum, an outgrowth of the forebrain, and the cerebellum, an outgrowth of the hindbrain.

THE CEREBRUM

The cerebrum is by far the largest part of the brain, accounting for about four fifths of the total weight of that organ. It is made up of two sections, called hemispheres. As a matter of fact, the name *cerebral hemispheres* is often used as an equivalent for cerebrum. Each of the hemispheres is divided, in turn, into four parts, known as *lobes*—the *frontal, parietal, temporal,* and *occipital lobes.*

The surface of the cerebrum is made up of thin layers of nerve tissue called *gray matter.* This consists of neuron cell bodies, dendrites and nonmyelinated axons, and supporting cells, which are known as *neuroglia.* The gray effect is due to the color of all these structures.

The gray matter making up the surface of the cerebrum is known as the *cerebral cortex.* It shows an intricate series of folds, called *convolutions,* which might be compared to an endless succession of hills and valleys. The hills are called *gyri;* the shallow valleys, *sulci;* the deep valleys, *fissures.*

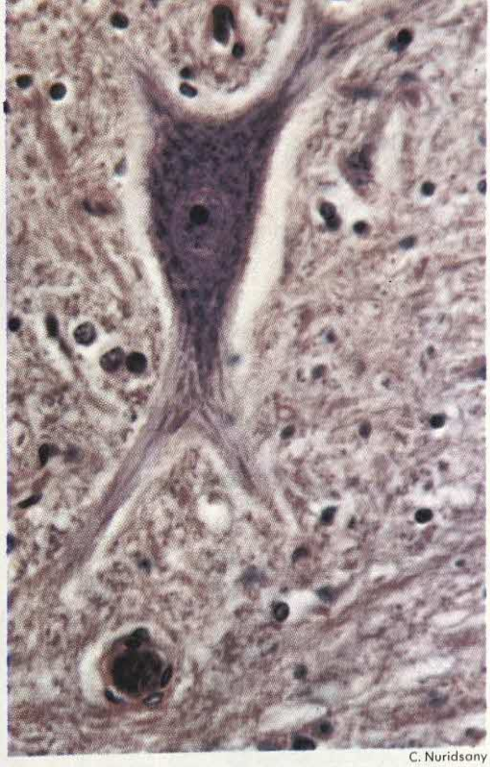
Underneath the gray matter is the *white matter* which makes up the bulk of the cerebrum. It consists of nerve fibers coated with myelin, which accounts for the *white matter,* which makes up the bulk of the surface downward, from the front backward, and from side to side. Still deeper within the two hemispheres of the cerebrum is some more gray matter. The neurons it contains serve as relay stations in the nerve pathways that lead to and from the cerebral cortex.

The remarkable development of the cerebral cortex accounts for the human ability to learn, to modify behavior as a result of experience, and to engage in abstract reasoning. If the cortex does not develop in a human being, he becomes incapable of learning and reasoning. Before the cerebral cortex can perform many of its functions, it must be awake, or conscious. A special system of nerve fibers going to the outer layer of the cortex produces this state of alertness, or wakefulness.

Different areas of the cerebral cortex,

when awake, perform different functions. The motor area, giving rise to impulses that cause muscular movements, is found in the rear part of the frontal lobes. It is made up of the gray matter immediately in front of the central fissure, or the fissure of Rolando, that separates the frontal and parietal lobes. The upper part of the motor area controls movements of the toes and feet. Below this, in order, are areas controlling movements of the legs, thighs, trunk, arms, hands, fingers, mouth, lips, tongue, throat, and larynx. The size of a given motor area depends upon the complexity of the muscles whose movements it regulates. For example, the area concerned with movements of the face is much larger than that which governs foot movements.

The *motor area* of the cerebral cortex controls groups of muscles on the opposite side of the body. Thus, if the upper part of the left frontal lobe's motor area is injured or becomes diseased, the movement of the toes and feet on the right side of the body are affected. This is because the nerve pathways in the brainstem cross over to the opposite side. The cranial nerves—nerves arising from the brain—do not cross over. Hence the face, head, and neck are affected on the side on which a brain injury occurs.

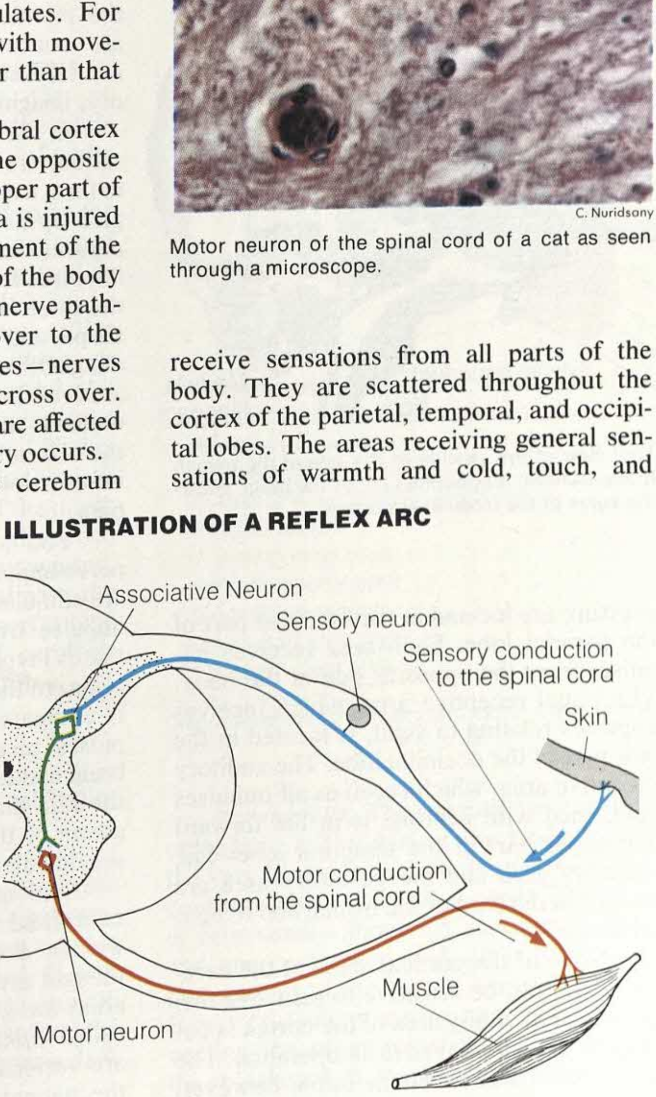


C. Nuridsony

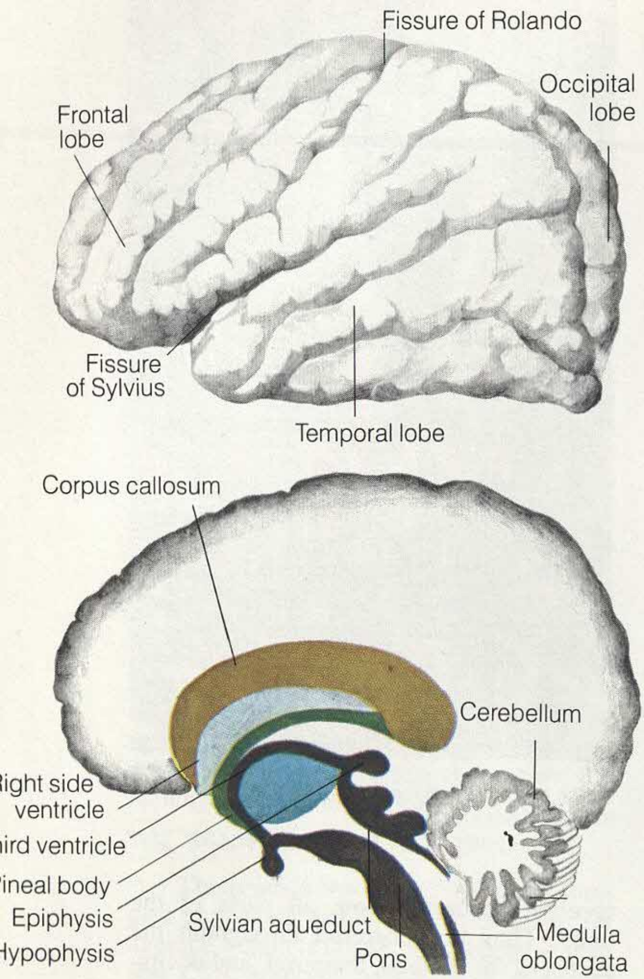
Motor neuron of the spinal cord of a cat as seen through a microscope.

The *sensory areas* of the cerebrum receive sensations from all parts of the body. They are scattered throughout the cortex of the parietal, temporal, and occipital lobes. The areas receiving general sensations of warmth and cold, touch, and

ILLUSTRATION OF A REFLEX ARC


Associative Neuron
Sensory neuron
Sensory conduction to the spinal cord
Skin
Motor conduction from the spinal cord
Muscle
Motor neuron

A diagram of a simple reflex arc. An impulse is received at a skin receptor site and is transmitted along a sensory nerve fiber to the spinal cord. There the impulse is transmitted along an associative nerve cell to a motor nerve cell. From the body of the motor nerve cell the impulse is then transmitted to a muscle fiber, stimulating a muscular response.



Top: view of the outside of the side of the human brain. Bottom: longitudinal cut of the brain, showing some of the internal structures.

pressure are located in the foremost part of the parietal lobe. Each area receives impulses from the opposite side of the body. The visual receptive area, which receives impulses relating to sight, is located in the rear part of the occipital lobe. The auditory receptive area, which receives all impulses concerned with hearing, is in the forward and upper part of the temporal lobe. The olfactory area and the gustatory area are located in the base of the frontal and temporal lobes.

None of the cortical areas of the cerebrum seem to be sensitive to pain. We feel no pain at all if any area of the cortex is cut or even if it is removed in an operation. The membranes that cover the brain, however, contain many pain fibers, and these must be anesthetized for neurosurgery. Apparently general sensations of pain are recorded in the prefrontal cortex and in the thalamus, which is in the forebrain. The cerebral cortex serves to let the sufferer know just what part of the body is being painfully stimulated.

The *association areas* of the cerebral cortex make up by far the largest part of the frontal and parietal lobes and a good deal of the temporal and occipital lobes. We cannot assign any definite motor or sensory functions to these parts. Rather, they deal with the internal activities of the brain. They are concerned with our most advanced mental faculties – learning, reasoning, memory, imagination, and personality.

In the association areas, separate sensations are combined and interpreted so as to form a meaningful impression. When you pick up an apple, for example, a train of separate impulses is set in motion. Certain impulses from the retina of the eye provide the brain with information about the size, shape, and color of the object you are handling. Other impulses from certain sensitive areas of the fingers inform the brain that the object is smooth and solid. Still others from the olfactory area of the nose convey the information that the object has a distinctive odor.

You are not aware of the separate nerve impulses that arise when your senses are stimulated by such an object. Yet each impulse travels along the sensory nerve that is involved as a special message to the brain. In the association area, each impulse is compared with memories of other impulses received in the past. Finally the brain makes the necessary interpretation of the data that have reached it. You become aware of the fact that the object that you see, handle, and smell is an apple.

The association areas are probably concerned with the symbols that make up written and printed words, speech, and thought processes in general. When these areas are injured or disturbed, a condition called *aphasia* sometimes results. There are various types of aphasia. In one kind, the patient is able to move his lips and tongue but cannot speak. In another kind, he is able to hear but cannot understand the meaning of spoken words. In still another, he cannot understand printed or written language, though the sense of sight remains unimpaired. All these conditions are due to faulty interpretation in the cerebral cortex.

THE CEREBELLUM

The cerebellum is in the rear part of the skull cavity. It is more or less oval in form and is composed of three parts. The small central part is called the *vermis*. The two large sections on either side of the vermis are known as the *cerebellar hemispheres*.

The surface of the cerebellum consists of a very thin layer of gray matter—the *cerebellar cortex*. Underneath it lies the white matter, consisting of large bundles of nerve fibers.

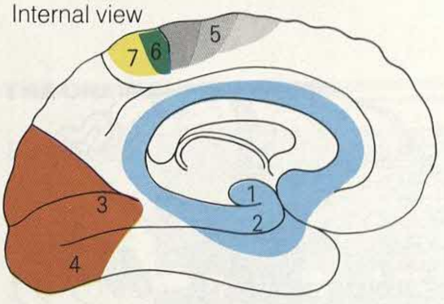
The cerebellum is considered to be the unconscious motor coordination center of the brain, responding to reflexes as well as to cortically planned movement. It helps us to maintain our balance at all times, telling us whether we are standing, walking, or lying down. By finding the right muscles, it assists in controlling all body movements. Were it not for the cerebellum, if you reached out your hand for something, it would go beyond or to one side of the mark. The equilibrium of the body is disturbed when the cerebellum is diseased or injured. The sufferer is unable to co-ordinate the muscle movements involved in performing a given act. However, no real paralysis takes place. Only central control is impaired.

THE BRAINSTEM

The brainstem includes the midbrain, the medulla, ad the pons.

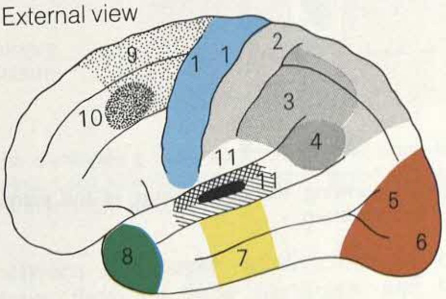
The midbrain. The midbrain—a part of the brainstem—lies between the cerebrum and the cerebellum. It serves as a pathway for nerve fibers leading to and from various areas of the brain and spinal cord. It also controls certain reflexes having to do with sight and hearing. Thus it constricts the pupil of the eye when we pass from a dark room to a lighted room.

Internal view



1 Olfactory area
2 Olfactive memories
3 Visual area
4 Area of visuopsychic association
5 Motor areas
6 Somatosensory area
7 Somatopsychic area

External view



1 Motor area
2 Somatopsychic area
3 Tactile memories
4 Speech blind area
5 Area of visuopsychic association
6 Visual area
7 Tasting area zone
8 Psychomotor area
9 Agraphia center
10 Acoustic area zone
11 Speech deaf area

Diagrams showing sensory and motor areas of the brain.

The medulla. The medulla, or medulla oblongata, is the part of the brainstem at the very base of the brain. It represents the continuation of the spinal cord. Though it is very small—about 2.5 centimeters long and one centimeter thick—it is a very important part of the central nervous system. It is a crossing place for nerve fibers connecting the other parts of the brain with the spinal cord. It controls respiration, regu-

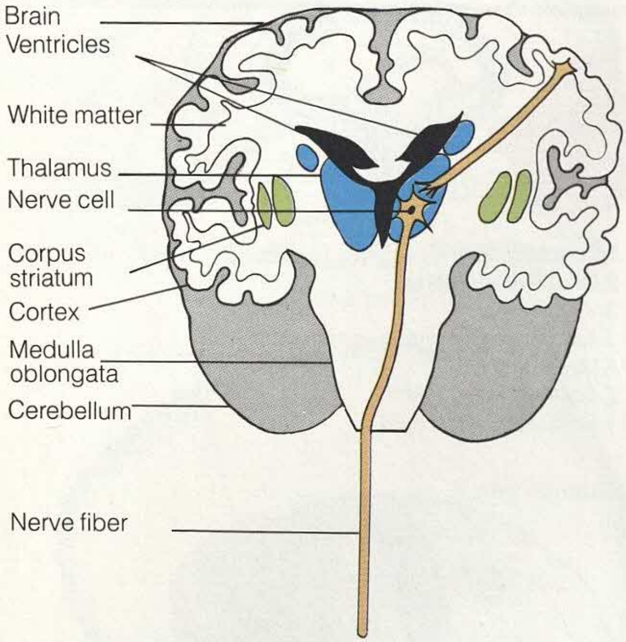


Diagram showing the connections of the spinal cord and the brain.

lates the heartbeat, and causes blood vessels to constrict or expand. Its impulses upward produce a state of consciousness. Because of the great number of vital centers packed in the medulla, an injury or disease that affects an area no larger than a pinhead may cause alarming damage to the whole system.

The pons. The pons is a bulge in the brainstem above the medulla. It contains the motor conduction paths connecting the cerebral cortex to the cerebellar hemispheres. It also serves as a bridge between the two hemispheres of the cerebellum and between the medulla and the cerebrum. Disease or injury to this part of the brain results in an impairment of the motor tracts leading from the brain to the spinal cord and, consequently, impairment of the associated motor functions. This means that if the pons is diseased or injured, it causes varying degrees of paralysis in the arms or legs on one or the other side of the body. In certain instances, the nerves of the face may be seriously affected.

THE SPINAL CORD

The spinal cord is a long, cylindrical mass of nerve tissue lying in the spinal canal. Its average length is about 45 centimeters in the adult male and about 42 centimeters in the adult female. It makes up only about two per cent of the weight of the central nervous system. It is surrounded and protected by the meninges and by the bony walls of the spinal canal.

The spinal cord is not perfectly cylindrical in shape but is somewhat flattened. Its diameter is not uniform. There are two pronounced enlargements—the cervical, in the upper part of the cord, and the lumbar, in the lower part.

Like the brain, the spinal column has both gray matter and white matter. In the spinal cord, however, the gray matter is on the inside, the white matter on the outside. In a cross section of the cord, the gray matter forms a rough sort of letter H, surrounded by white matter.

The gray matter serves as an important reflex center, receiving impulses carried along a vast number of sensory fibers. In many cases, reflex action is produced without the assistance of the cells in the brain. This is true of many involuntary movements of the arms and legs. The more complex the movement, the greater is the need for assistance from the higher centers in the brain. The gray matter is also a central switching station for nerve impulses coming into the cord and leaving it. The nerve cells in this area, under the control of the cerebellum, permit a smooth, purposeful movement in a group of several muscles, such as a coordinated movement of both arms.

The white matter of the spinal cord consists of thick bundles of nerve fibers, coated with myelin. The white matter is divided into a left half and a right half by two fissures running down the front and back of the cord. Each half is made up, in turn, of three distinct bundles of nerve fibers, forming columns, or *funiculi*. Those in front are called anterior; those at the side, lateral; those at the back, posterior.

Some of the fibers in the funiculi carry impulses up the cord to the brain. They are found in the posterior columns. The sensory impulse that begins, let us say, in the finger, is carried by a nerve fiber to cells in the gray matter of the cord. From there it is relayed by the fibers of the white matter to the gray matter of the brain. Other bundles of fibers carry impulses from the brain to the motor cells of the spinal cord. These fibers are found in the anterior columns and, to a certain extent, in the lateral columns. Impulses from the brain—the motor impulses—begin in the gray matter of the brain, descend through the white matter of the brain and cord, and end in the motor cells that are to be found in the gray matter of the cord.

THE MENINGES

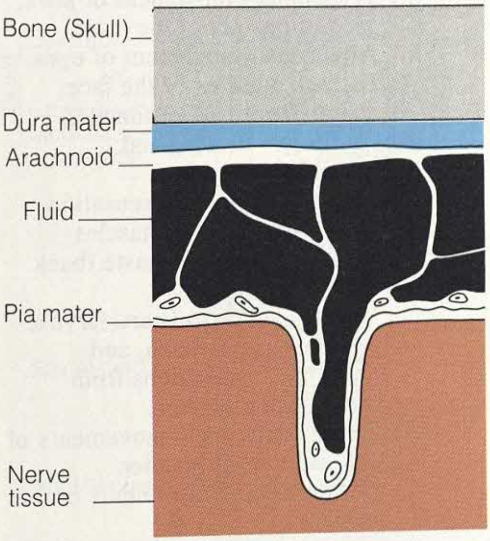
The brain and spinal cord are enveloped in three membranes, called the meninges. The meninges provide a framework that supports and protects the brain and spinal cord. The innermost of these membranes is the *pia mater;* the outermost, the *dura mater.* Between these two membranes is the *arachnoid.*

The *pia mater* is a thin, delicate structure, adhering closely to the surface of the brain and spinal cord. It serves as a supporting cover for the brain and cord and also carries the blood vessels that supply the outer surfaces of these two areas.

The *arachnoid* is thin, like the pia mater. It is separated from the latter by a space containing a watery fluid—the *cerebrospinal fluid.* This fluid is transparent and has a slightly yellowish tinge. It varies in quantity in different individuals and in different diseased conditions. The cerebrospinal fluid acts as a cushion, protecting the brain and spinal cord from injury. It also serves somewhat as a nutrient medium for the nerve cells.

The *dura mater* is the outermost of the three meninges. It adheres closely to the bones of the skull. In the spinal column, it hangs rather loosely. It is not attached to the surrounding bones of the spinal canal as it is to the bones of the skull. In the skull, the dura mater is a thick double membrane. Its inner layer forms partitions that dip between the larger subdivisions of the brain. Between these partitions, and between the two layers of the dura mater, are enclosed large sinuses, or hollows. Venous blood from the brain collects in these sinuses before it leaves the brain.

THE CRANIAL MENINGES



The meninges protect and support the brain and spinal cord. Cerebrospinal fluid is found between the arachnoid and pia mater.

PERIPHERAL NERVOUS SYSTEM

Forty-three pairs of nerves lead from the brain and spinal column to other parts of the body. These cerebrospinal nerves make up the peripheral nervous system. The sensory fibers extend to the skin, muscles, and joints and also to various sense organs. The motor fibers extend to muscles, glands, and blood vessels.

Cranial nerves. There are twelve pairs of cranial nerves leading from the brain. The first four pairs are attached to the cerebrum; the last eight pairs, to the hindbrain. They supply almost exclusively the area about the head, face, and upper part of the neck. Their names and functions are as follows:

(1) Olfactory—smell.
(2) Optic—sight.
(3) Oculomotor—movement of eyes.

(4) Trochlear – movement of eyes.
(5) Trigeminal – movement of jaws; sensations about the face.
(6) Abducens – movement of eyes.
(7) Facial – muscles of the face; taste (front part of tongue).
(8) Auditory – hearing and equilibrium.
(9) Glossopharyngeal – sensation and movement of muscles around the throat; taste (back part of tongue).
(10) Vagus – motor to heart, larynx, esophagus, stomach, and intestines; sensations from chest and abdomen.
(11) Spinal accessory – movements of the neck and shoulder.
(12) Hypoglossal – movements of the tongue.

Spinal nerves. Thirty-one pairs of nerves originate in the spinal cord. Each of these nerves is attached to the cord by two roots. One is the afferent, or posterior, root, which enters the cord at the rear. The other is the efferent, or anterior, root, which issues from the front part of the cord. The spinal nerves are arranged in groups and are named after the region of the spinal cord from which they emerge as follows:

(1) Cervical – eight pairs.
(2) Thoracic – twelve pairs.
(3) Lumbar – five pairs.
(4) Sacral – five pairs.
(5) Coccygeal – one pair.

The nerves of the first four of these groups are further identified by numbers. Thus we refer to the second cervical, the fifth thoracic and third lumbar.

In many cases, groups of spinal nerves form networks, called *plexuses*. Among the most important of these are the cervical, brachial, and lumbosacral plexuses.

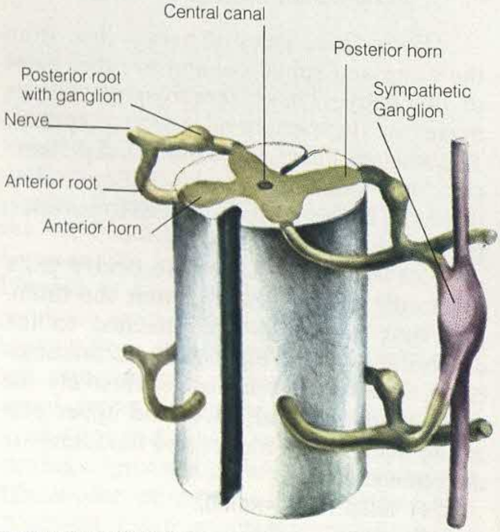
The *cervical plexus*, lying in the upper neck, involves divisions of the first four cervical nerves. It supplies nerves to the skin of the head and neck and the muscles of the tongue, neck, and shoulder.

The *brachial plexus*, formed chiefly by elements of the last four cervical and first thoracic nerves, lies in the lower neck. It supplies the chest, shoulder, and arm.

The *lumbosacral plexus* is made up of divisions of the lumbar, sacral, and coccygeal nerves and supplies the lower body and the legs.

The nerves that lead from plexuses such as those that are mentioned above receive distinctive names.

Cross section of the spinal cord. The gray matter forms a rough H surrounded by white matter. Ganglia, or masses of nerve tissue, link the autonomic nervous system with the central nervous system.



CROSS SECTION THROUGH THE HUMAN SPINAL CORD

AUTONOMIC NERVOUS SYSTEM

In addition to the central, or cerebrospinal, nervous system and the peripheral nervous system, there is an *autonomic nervous system*. It is so called because it is self-acting and not under the control of the "will" – a function of the higher cortical centers.

The autonomic nervous system is a built-in control, acting upon smooth muscles and glands. It services structures such as the alimentary canal, lungs, heart, glands, and urinary bladder and keeps them functioning properly. If it were not for the autonomic nervous system, life would become impossibly complicated. Our attention would have to be devoted at all times to such matters as speeding up or slowing down the heartbeat, bringing about secretion from different glands in the body, checking these secretions, and dilating or constricting the pupil of the eye.

The autonomic system is made up of two divisions – the *sympathetic* and the *parasympathetic*. In both, *ganglia*, or masses of tissue containing nerve-cell bodies, serve as connecting links between the central nervous system and the body structure served by the autonomic system. In the sympathetic division, the ganglia form two series of chains, one on either side of the vertebral column. In the parasympathetic division, the ganglia do not lie along the spine but are distributed within or near the organs upon which the nerves act. The processes arising from nerve-cell bodies in these ganglia have no myelin covering, but only a connective tissue sheath.

The two divisions of the autonomic system act in opposite ways on each organ. Generally the sympathetic division stimulates body activities so as to satisfy increased demands. The parasympathetic, on the other hand, acts somewhat like a brake. For example, the sympathetic speeds up the heartbeat and causes secretion from the adrenal gland. The parasympathetic slows down the heartbeat and checks secretion from the adrenal. In certain cases, however, these roles are reversed. Thus it is the parasympathetic division that brings about secretion from the salivary glands, while the sympathetic checks this secretion.

NERVOUS SYSTEM DISORDERS

The diseases of the nervous system – those affecting the brain, spinal cord, and nerves of the body – form the subject matter of the branch of medicine called *neurology*.

Acute infections of the nervous system may be caused by the action of various bacteria and viruses. These infections may spread to the nervous system from other parts of the body, or they may enter the system directly through the bloodstream. Syphilis, an infection caused by bacteria known as spirochetes, often attacks the brain in the later stages of the disease. It may bring about *general paresis*, which is a paralysis marked by loss of reason and memory, speech disturbance, and increasing muscular weakness. Bacteria are often responsible, too, for *meningitis*, an acute inflammation of the meninges.

THE HUMAN NERVOUS SYSTEM

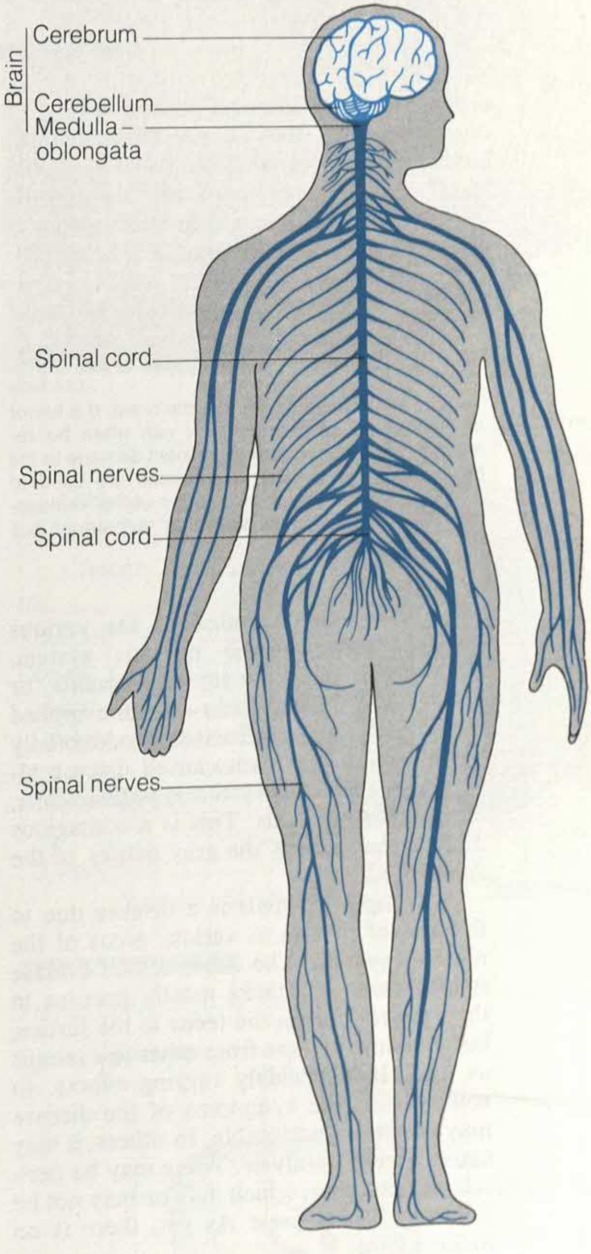
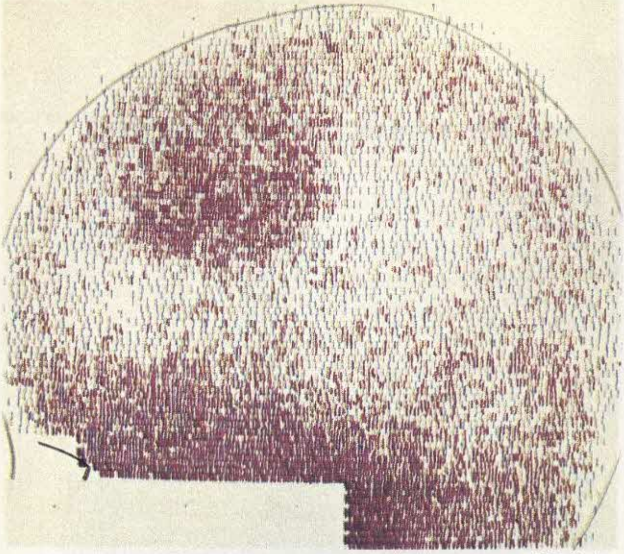


Diagram showing the connection of the brain, spinal cord, and peripheral system nerves.



C.E.A, Saclay

Tumors sometimes develop in the brain. If a tumor is recognized early enough, it can often be removed surgically without permanent damage to the brain. Many specialized techniques are used to diagnose brain tumors. Above, the use of radioactive tracers and special scanning techniques has revealed a tumor.

Viruses are responsible for various diseases affecting the nervous system. They are responsible for *encephalitis,* or inflammation of the brain—a name applied to a varied group of diseases. Undoubtedly the most familiar virus-caused disease attacking the nervous system is *poliomyelitis,* or infantile paralysis. This is a contagious disease that affects the gray matter of the spinal cord.

Multiple sclerosis is a disease due to the loss of myelin in various areas of the nervous system. The cause of this disease is unknown. It attacks mostly persons in the age group from the teens to the forties, but it claims victims from other age groups as well. It has widely varying effects. In some cases, the symptoms of the disease may be hardly noticeable. In others, it may cause severe paralysis. There may be periods of remission, which may or may not be followed by relapses. As yet, there is no definite cure.

Injury to the brain, spinal cord, or nerves may have disastrous effects. A severe blow to the head, affecting the brain, may result in insanity or death. Various degrees of paralysis may be caused by injuries to the spine. Nerve injuries may affect the functioning of various parts of the body.

Vascular diseases—those attacking the blood cells and blood vessels—often affect the nervous system. Hardening of the arteries in the brain—a condition known as *cerebral arteriosclerosis*—interferes with the blood supply and causes the brain to degenerate. It may ultimately result in senility. High blood pressure may cause a blood vessel in the brain to rupture suddenly. The escaping blood may destroy nerve-cell bodies and fibers in its path and produce an *apoplectic stroke,* which will paralyze various muscles of the body. A stroke may be brought on by the bursting of a blood vessel in the brain due to cerebral thrombosis—the clotting of blood in the blood vessel. Diseases of this kind are particularly common after middle age.

Progress has been made in the treatment of apoplectic stroke. Formerly the patient was kept as quiet as possible for a long time in order to prevent further strokes. The new approach is to start active treatment as early as a week after the stroke occurs, if the patient's condition permits. This treatment includes massage, manipulation, and electric stimulation of muscles to keep them from deteriorating, plus such active exercise as the paralyzed limbs permit. Exercise may be carried on in water in order to lighten the weight on an affected limb. Preventive measures, too, have been improved.

Toxins, or poisons, from diseases in other parts of the body, especially the lungs, may spread to the brain. Alcohol and narcotic drugs, such as morphine, produce various toxic effects. Lead poisoning, common among painters, damages various cells in the front part of the spinal cord. It may bring about paralysis in the arms or legs.

Tumors sometimes develop in the brain. As a tumor formation expands, it presses upon cell bodies and fibers. The majority of brain tumors can be operated upon if they are recognized early enough, and they may have no serious aftereffects. However, if their growth results in the destruction of considerable nerve tissue, the damage may be irreparable.

THE EYE AND VISION

by S. Howard Bartley

The sense of vision is one of the most versatile of all senses. It supplies us with information about objects at very close range, at a great distance, and at an infinite number of distances between these two extremes.

We become aware of objects through the sense organ known as the *eye*.

Rays of light pass through a transparent part of the eyeball, penetrate through the inner part of the eye, and fall upon a layer of sensitive tissue. As a result impulses arise, and these impulses are carried by way of nerve fibers to the brain. Here the impulses give rise to the sensation of sight.

THREE LAYERS

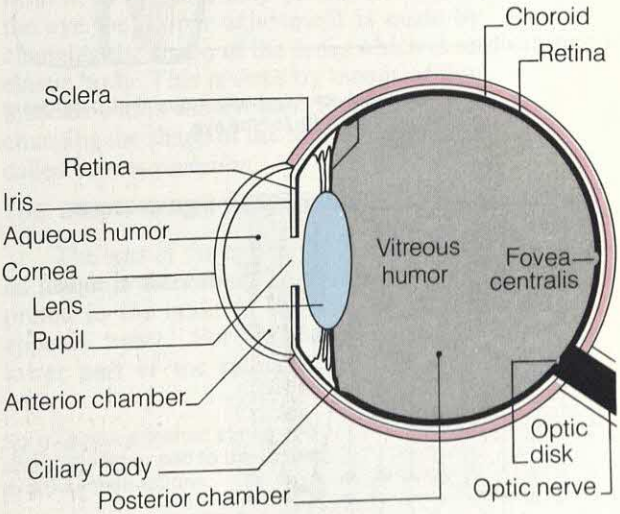
The eye, which is enclosed in a bony cavity called the *socket,* is more or less spherical in shape and is about 2.5 centimeters in diameter. It can be turned in different directions by six muscles, attached at one end to the eyeball and at the other end to the wall of the socket.

The eyeball wall, which encloses the liquid and semiliquid interior sections, is made up of three layers. The outermost one is the tough *sclera,* which protects the delicate inner structures of the eye. We can see part of this coat. It is what we call the "white of the eye". In front there is a circular, transparent area, called the *cornea.*

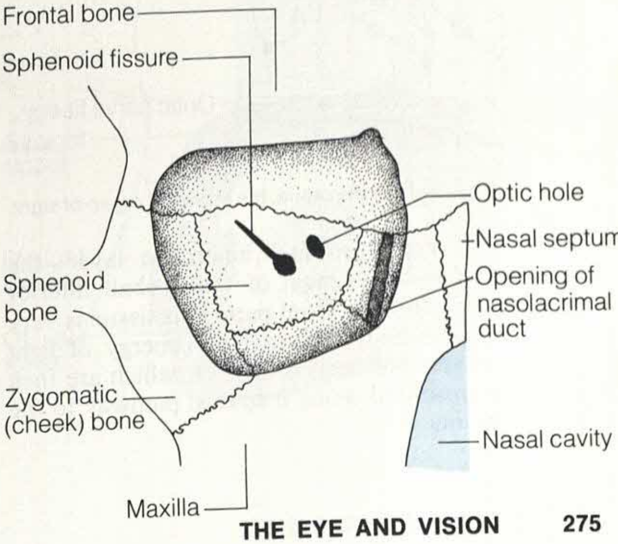
The outer surface of the sclera is lubricated by tear fluid, secreted by the *lachrymal,* or tear, *gland.* From the eye surface the fluid passes into small tubes – the *lachrymal ducts* – and from these into the nose. Protection for the outer surface of the eye is provided by the *eyelids.* These useful structures close as a result of reflex action when something is about to touch the eye.

The middle layer of the eye wall is known as the *choroid* coat. It carries a multitude of small blood vessels, which extend throughout the inner part of the eyeball except in front, where there is a hole, called the *pupil* of the eye. Surrounding the pupil is a circular band, called the *iris,* which gives the eye its color.

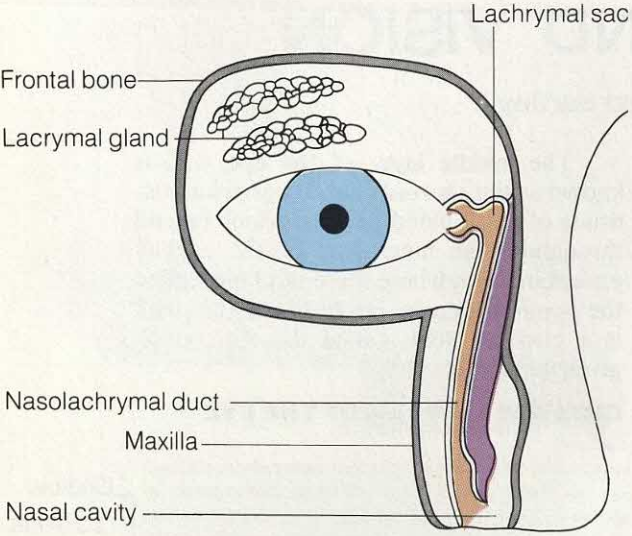
CUTAWAY DIAGRAM OF THE EYE



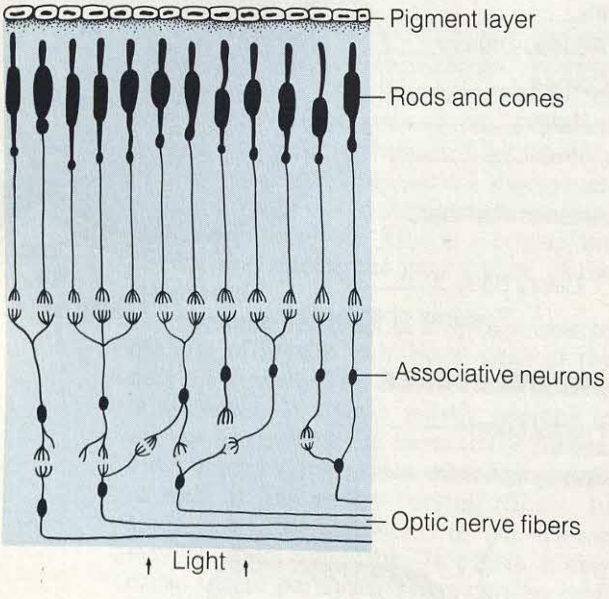
THE EYE SOCKET



Top right: a cutaway diagram of the eye, showing its major parts. Bottom right: the eye socket, or orbital cavity, the protective enclosure for the eyeball formed by the skull bones.



The lachrymal, or tear, apparatus that provides a protective fluid bath for the eye.



The layers of the retina, the essential organ of sight.

The third and innermost layer—the *retina*—lines most of the eyeball interior excluding the front part. This tissue is very sensitive. It converts the energy of light waves into nerve impulses, which are then transmitted along a special pathway to the brain.

RETINA

The retina consists of several layers, of which the most important are the *rods* and *cones,* the *bipolar cells,* and the *ganglion cells.*

The rods and cones are curiously shaped nerve cells that are sensitive to light. Impulses arise in them when they are struck by light rays. As a result other impulses are set up in the bipolar cells. These impulses are then transmitted to the brain by way of the fibers of the ganglion cells. The fibers make up a cablelike bundle, called the *optic nerve*, which issues from the back of the eye.

The rods are sensitive to far smaller amounts of light than the cones. Therefore, they are responsible for vision in dim light. Cones are particularly concerned with the perception of fine detail and of color. The rods are sensitive to light because of a chemical reaction brought about by the light rays that enter the eye. The outer part of the rods contains a red pigment called *visual purple,* or *rhodopsin.* When acted upon by light, it decomposes into a substance called *retinene* and then into vitamin A and a protein. The vitamin A and the protein are later reconverted into visual purple. A certain amount of vitamin A is lost in the process. This loss must be made good by fresh stores of vitamin A, supplied through the circulation. If a person's diet is lacking in this vitamin, he will not be able to see well in dim light—a condition called *night blindness*. It is believed that much the same kind of chemical reaction takes place in the cones.

Rods and cones are not uniformly distributed throughout the retina. A small region in the center, called the *fovea centralis,* contains only cones. This region is concerned with acute vision. The cones are distributed more and more sparsely toward the edge of the retina, while the relative number of rods increases. We see clearest in daylight by using the fovea centralis. At night, we see by using a region somewhat to the side. We are blind at all times to objects that cast their images only on the part of the retina where the optic nerve leaves the eye. There are no rods and cones in that part of the retina, which is called the *optic disk*. This results in a *blind spot* in the field of vision.

INTERNAL STRUCTURE

Thus far we have described the wall of the eye, with its three layers – the sclerotic coat, the choroid coat, and the retina. Let us now examine the internal structure of the organ. A short distance behind the cornea is the elastic crystalline *lens*, which focuses the light rays entering the eye. The lens, which is supported by a hammocklike ligament, is transparent in the case of a healthy eye. Sometimes it becomes clouded – a condition called *cataract*. In the commonest type of cataract – senile cataract, generally found in persons over fifty years of age – vision is gradually lost as the condition develops. To restore sight, the lens is removed and special glasses are provided to take its place. In other types of cataract the cloudiness may disappear more or less completely in time. This is particularly true in the case of cataract caused by perforation of the lens, due to injury.

The interior of the eyeball is divided by the crystalline lens and its supporting structures into two chambers. The one in front of the lens is filled with a watery solution called *aqueous humor*. The other chamber, occupying the space between the lens and the retina, is much larger. It contains a jellylike substance called *vitreous humor*.

THE EYE AS A CAMERA

Light comes to us in a series of waves. Different wavelengths excite different sensations of color when they strike the retina. The eye is not equally sensitive to light rays of all wavelengths. Certain rays will not result in any sensation of vision. These are the ultraviolet and infrared rays, among others.

We see objects because waves of light are reflected from them and enter the eye. The eye has often been compared to a camera. In the camera, light reflected from an object passes through a lens, is focused on a film at the back of the camera, and forms a small image. In the eye, reflected light passes through the crystalline lens and is brought to a focus on the light-sensitive retina. An adjustable diaphragm in the camera increases or decreases the amount of light that reaches the film. In the eye this sort of adjustment is made by the iris. Its opening can be made wider or narrower by means of muscles radiating from the inner rim of the iris.

Rays of light from a distant point are brought to a focus closer to the camera lens than rays reflected from nearby objects. To cause these dissimilar rays to be focused sharply on the film, the camera lens must be moved nearer to the film or farther away from it, as the case may be. In the case of the eye the proper adjustment is made by changing the shape of the lens, which is an elastic body. This is done by means of tiny muscles within the eyeball. The process of changing the shape of the lens in this way is called *accommodation*.

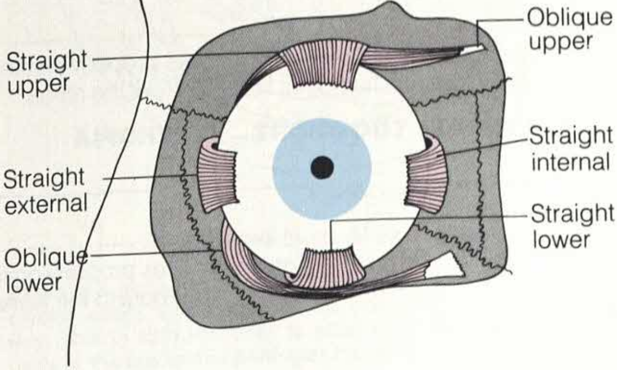
THE BRAIN INTERPRETS IMAGES

The lens of the eye produces an inverted image in the retina. This image is interpreted in the brain in such a way that it appears erect. For example, when the lower part of the retina is stimulated by

Six muscles, attached at one end to the eye socket and at the other end to the eyeball, turn the eyeball in different directions.

MUSCLES OF THE EYE

(front view of right eye)



light rays reflected from a given object, it seems to us that the object is in the upper part of the field of vision. If we put on glasses which focus the incoming rays in such a way that upright images appear in the retina, everything seems topsy-turvy at first. In time, however, we learn to make the correct interpretation. If we remove the glasses and let inverted images be formed on the retina, we must learn all over again how to interpret the images.

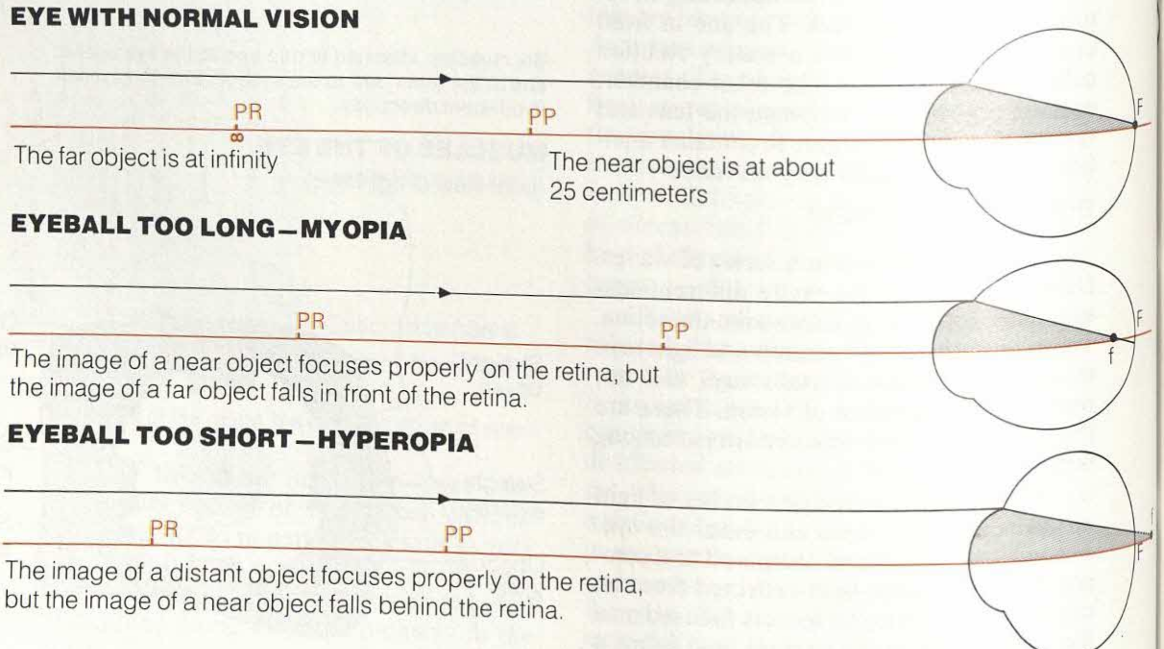
The eye is able to adapt to the various levels of light that one meets in everyday life, except to such extreme intensities as those of the sun or of arc lights. There is a striking example of this faculty of adaptation when we enter a movie theater from broad daylight. At first, little is visible. Soon, however, darkness gives way to dim illumination, which enables us to find our way to a seat.

LOCATING OBJECTS

It is important for our sense of vision to tell us where objects are. This is called *localization.* When we try to decide where an object is, our decision will depend upon what we think the object is. For instance, if you saw an illuminated white rectangular area in a dark room, you might consider it to be a movie screen. In that case, it would seem to be a few meters away. Suppose you thought of it as a blank filing card. The bright rectangular area might seem to be only centimeters away from your eyes. In a case such as this, the observer does not have to analyze the situation at length in order to place an object. He makes an instant judgment as to what the object is, and he sees it at what he considers the appropriate distance.

If one object is partly covered by another, the covered one will appear to be farther away. This is called *overlay.* Elevation is another factor. Objects lying higher in the field of sight generally appear farther away than lower-lying ones. This effect is sometimes reversed, in which case the higher object seems nearer. Relative size also helps to localize objects: smaller ones seem

In some people the eyeball is too long or too short and the image falls in front of or behind the retina. Such conditions—nearsightedness and farsightedness—can usually be corrected by glasses or contact lenses.


EYE WITH NORMAL VISION
PR
∞
PP
F
The far object is at infinity
The near object is at about 25 centimeters
EYEBALL TOO LONG—MYOPIA
PR
PP
F
f
The image of a near object focuses properly on the retina, but the image of a far object falls in front of the retina.
EYEBALL TOO SHORT—HYPEROPIA
PR
PP
f
F
The image of a distant object focuses properly on the retina, but the image of a near object falls behind the retina.

farther away. Apparent brightness is still another factor in determining apparent location. Usually the brighter of two otherwise similar objects seems to be nearer. An object appears to move toward the observer when it is made brighter, and to recede when it is dimmed.

Still another important factor in the localization of objects is *parallax*. This effect is obtained as one moves past objects or simply moves one's head. Certain objects will seem to stand still, while others will seem to move in the direction opposite the observer's motion. The "still" objects will appear to lie beyond those that "move." For example, suppose the train on which one is riding moves past a telephone pole and a building. The pole will apparently move in a direction opposite that in which the train is moving, but the building will stand relatively still. The building will seem to be farther away.

The fact that we have *binocular vision*—that is, vision through two eyes—helps us to perceive depth. Each eye gets a somewhat different view of a given object, particularly at close range. When the two retinal images are interpreted together in the brain, we have a clear three-dimensional view. The depth of an object is not so clearly perceived when we look at it through one eye.

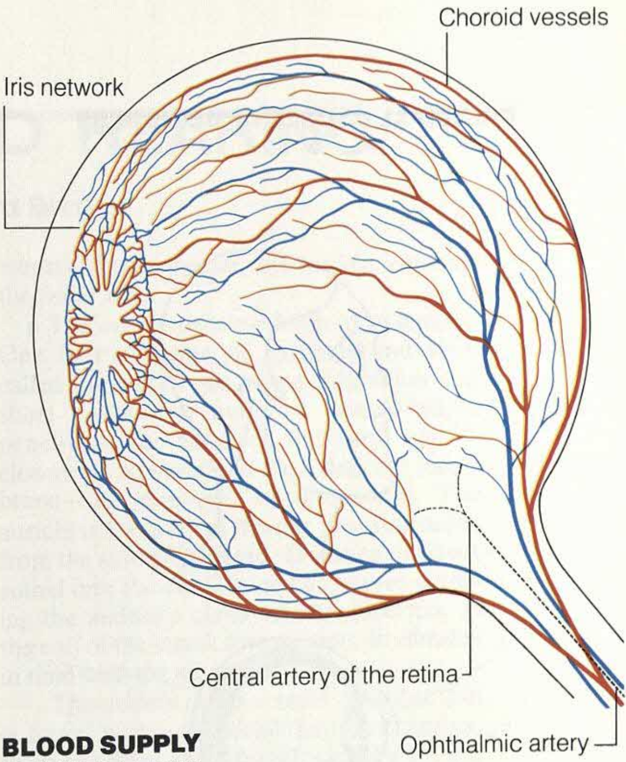
The interpretation of objects in the brain may not correspond to their actual appearance. In that case there will be a series of optical illusion.

ABNORMALITIES

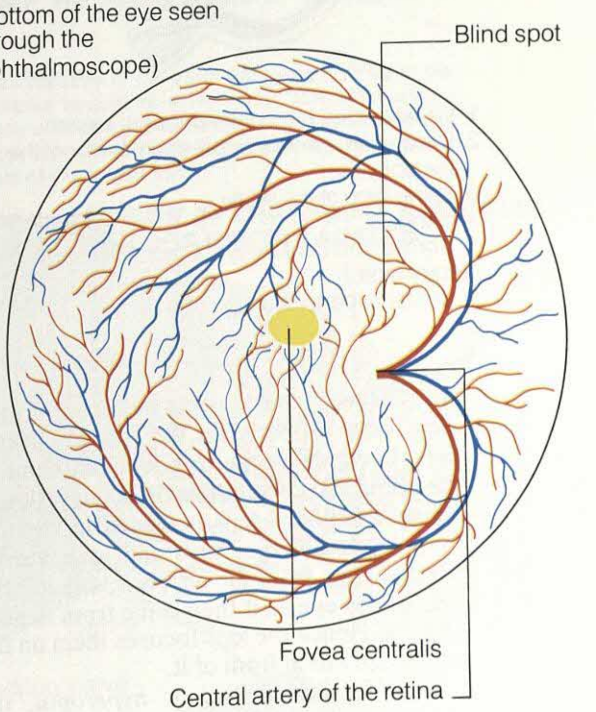
The vision of certain persons is limited or defective. The crystalline lens may refract rays of light effectively enough, but the retina is either farther away from the lens than in a normal eye or nearer to the lens. In such cases special artificial lenses, spherically curved, must be prepared in order to provide normal vision. These lenses may be set in spectacle frames or may be applied directly to the eyeball in the form of contact lenses.

In the condition called *myopia*, or nearsightedness, the eyeball is longer than it would be in normal eyes. When light rays

BLOOD SUPPLY OF THE EYEBALL

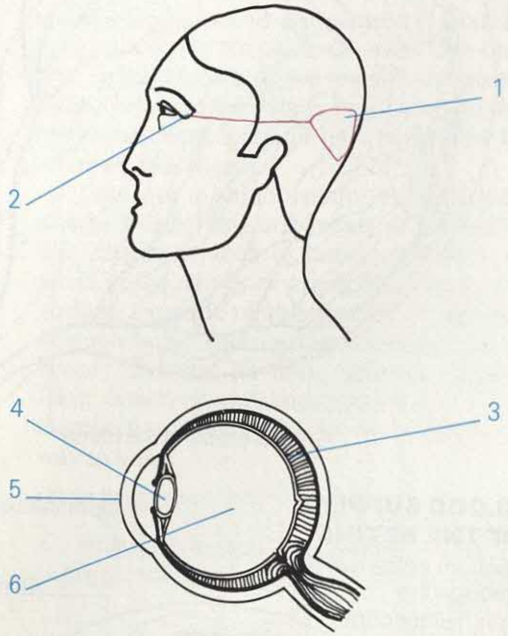


BLOOD SUPPLY OF THE RETINA
(bottom of the eye seen through the ophthalmoscope)



Blood is supplied to the eye through the internal carotid artery, which supplies the ophthalmic artery. This in turn branches to supply the various parts of the eye and in particular the retina.

PRINCIPAL CAUSES OF BLINDNESS



1. Visual center: tumor hemorrhage, spasm
2. Separation, nerve compression, tumor of the hypophysis
3. Separation of the retina
4. Cataract
5. Cornea and conjunctiva: scars, infection, trachoma
6. Ocular hypertension, glaucoma

are reflected from objects near to the eye, they focus properly on the retina. Distant rays, however, come to a focus in front of the retina. To correct this defect in vision, a concave artificial lens is placed in front of the eye. It diverges rays and makes even parallel rays from far-off objects reach the lens of the eye as if they came from nearby objects. Hence the lens focuses them on the retina and not in front of it.

In farsightedness, or *hyperopia,* the eyeball is shorter than it would be in normal eyes. Rays reflected from far-off objects are focused properly on the retina. Rays from nearby objects are focused behind it. A convex lens is used to remedy the defect of hyperopia.

Certain corrective lenses are in the form of prisms. They bend incoming rays of light so that the eyes need to converge ("turn in") either more or less than without glasses to obtain the same visual results. These lenses prevent a person from seeing double.

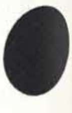
Other lenses are intended to remedy the condition called *astigmatism,* in which light rays are brought to focus on the retina not in the form of sharp points, but as short lines. Astigmatism is due to the fact that the crystalline lens has raised or depressed areas on its surface. A person suffering from this condition must wear lenses with raised or depressed areas to compensate for corresponding defects in the crystalline lens.

VISUAL ACUITY TESTS

In fitting glasses, sharpness of vision, or *visual acuity,* is an important factor. There are several standard tests for visual acuity. One of the most common is the Snellen Chart. It consists of several lines of letters of different sizes. A person with normal vision will be able to read letters farther away than the person with poor visual acuity. A person is said to have 20/20 vision if at six meters (20 feet), the standard distance, he can read letters that a person with normal vision can read at the same distance. If at six meters a person can just read letters that are so big that the person with normal vision can read them at 12 meters (40 feet), twice the standard distance, the person is said to have 20/40 vision.

The presence of the blind spot can be easily shown. Keep your left eye closed and focus on the star, holding the page close to you. Then gradually move the page away. At a distance of about 20 or 25 centimeters, the black spot will become invisible. Its image has fallen on the optic disk, where there are no rods or cones.

★



THE EAR AND HEARING

by S. Howard Bartley

When we hear sounds, we really become aware of waves of air striking our ears. The waves arise as the result of vibrations caused by a disturbance such as the ringing of a bell or the tooting of a horn. The vibrations are set off in a series of alternating compressions and rarefactions.

All the air waves in our vicinity strike our ears, but not all produce the sensation of sound. Human ears register only the vibrations ranging from about 16 hertz to between 20,000 and 30,000 hertz: that is, sound waves having a frequency of from 16 to between 20,000 and 30,000 cycles per second.

PARTS OF THE EAR

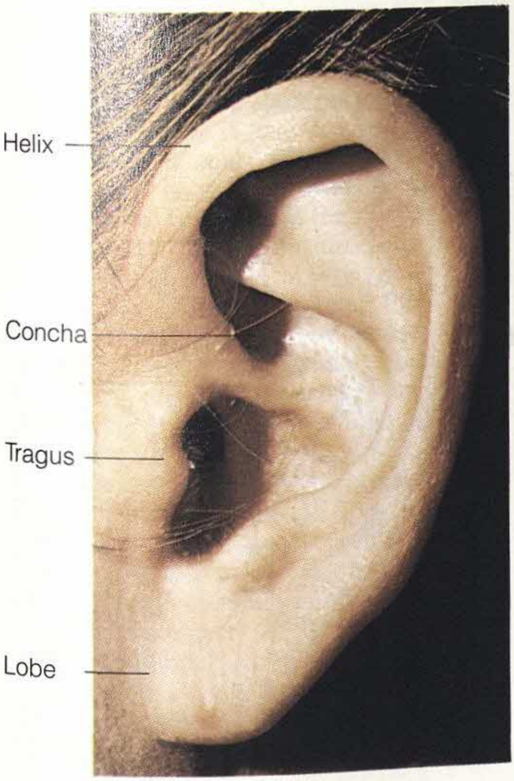
The ear, in which we receive the vibrations, is divided into three compartments—the *outer ear*, the *middle ear*, and the *inner ear*.

The *outer ear* is made up of two parts. One is a structure of cartilage and skin, called the *auricle*, or *pinna*. The other is a short canal—the *auditory canal*—which penetrates the bone of the skull and is closed at the inner end by a delicate membrane—the *eardrum*, or *tympanum*. The auricle is the part of the ear that protrudes from the side of the head. It serves to direct sound into the ear. The sound waves entering the auditory canal set the eardrum, at the end of the canal, into motion. It vibrates in time with the air waves.

The *middle ear* is a small chamber that is found within the skull. In this chamber, there are three small bones, called *ossicles*, which are joined together. They form a

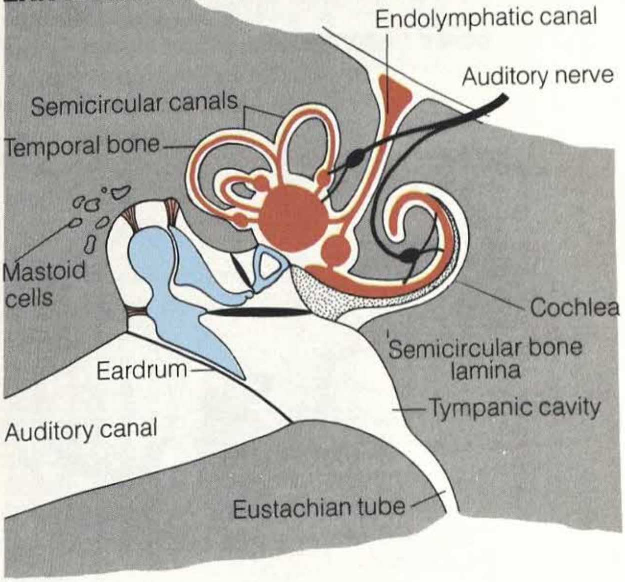
D. Lesec

THE EXTERNAL EAR

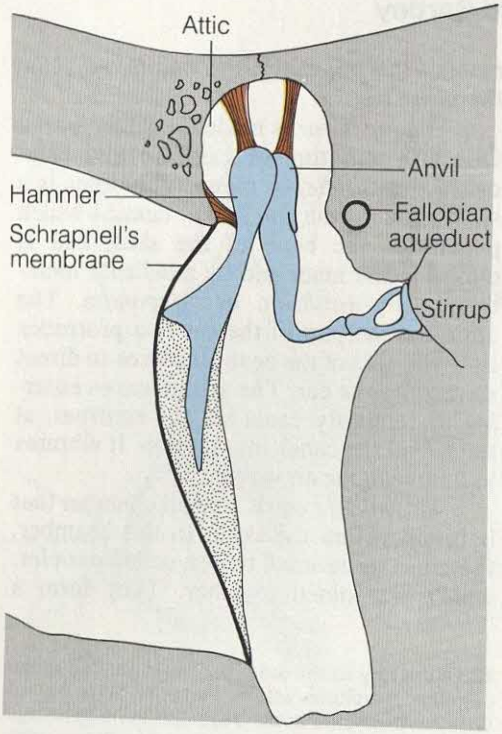


The simplicity of the outer ear gives no clue to the complex structures within. Left: the outer ear—a fleshy oval-shaped appendage and the beginnings of the canal leading to the middle ear. Below: diagram of the middle ear.

CROSS SECTION OF THE MIDDLE AND INNER EAR WITH MAJOR PARTS LABELED

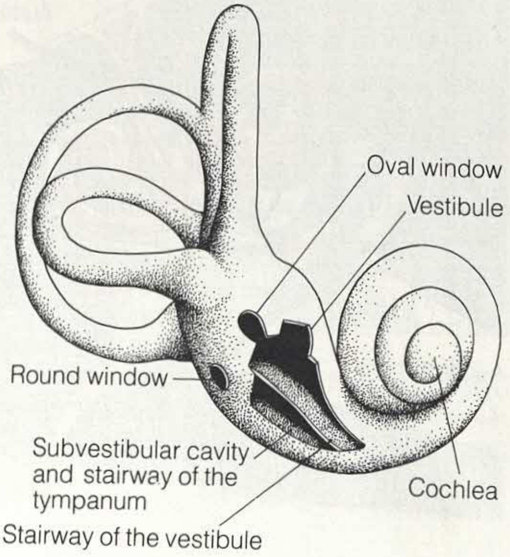


LONGITUDINAL SECTION OF THE TYMPANIC CAVITY

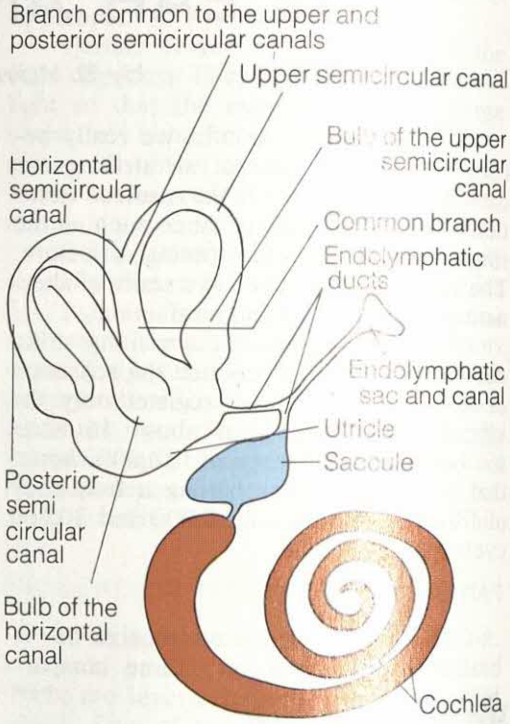


Sound waves pass through the tympanic cavity (upper left), cause vibrations of the bones of the middle ear (lower left), and pass into the inner ear containing the cochlea (upper right), and, on it, the organ of Corti (lower right).

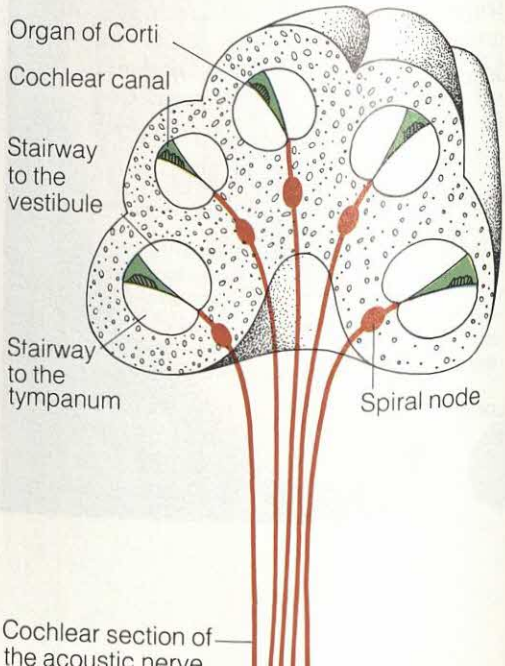
BONY LABYRINTH


Oval window
Vestibule
Round window
Subvestibular cavity and stairway of the tympanum
Cochlea
Stairway of the vestibule

MEMBRANOUS LABYRINTH


Branch common to the upper and posterior semicircular canals
Upper semicircular canal
Bulb of the upper semicircular canal
Horizontal semicircular canal
Common branch
Endolymphatic ducts
Endolymphatic sac and canal
Utricle
Saccule
Posterior semi circular canal
Bulb of the horizontal canal
Cochlea

SECTION THROUGH THE COCHLEA


Organ of Corti
Cochlear canal
Stairway to the vestibule
Stairway to the tympanum
Spiral node
Cochlear section of the acoustic nerve

connecting link between the eardrum and the inner ear. The ossicles act as a lever system, transmitting to the inner ear the vibrations that strike the eardrum. The outermost of the three bones is attached to the eardrum. Because of its shape this bone is commonly called the *hammer*. The middle bone vaguely suggests an *anvil*, and that is what it is called. The name *stirrup*, applied to the innermost bone, is very apt: the resemblance to a stirrup is quite striking. These bones are also called by the Latin names *malleus* ("hammer"), *incus* ("anvil"), and *stapes* ("stirrup"). The footplate of the stirrup fits into an *oval window* called the *fenestra ovalis*, beyond which lies the inner ear. This window has a membrane stretched across it. A little below the oval window is a *round window*, also closed by a membrane.

A small tube, called the *Eustachian tube*, runs from the middle ear to the back of the nose. The middle ear connects by means of this tube with the outer air, whenever the tube is open. It opens only in the act of swallowing. Whenever this takes place, air passes up the tube into the middle ear and causes the air pressure on both sides of the eardrum to be equalized. If the Eustachian tube is blocked because of a cold in the head, part of the air in the middle chamber is absorbed into the blood. There is then more pressure on the outside of the eardrum than on the inside, and the eardrum cannot vibrate freely. Sounds are imperfectly transmitted, and the person becomes slightly deaf. Infections of the middle ear may occur when organisms in the mouth or nose make their way into the middle ear by way of the interconnecting Eustachian tube.

The outer and middle ears serve only to transmit vibrations to the inner ear, where we find the basic organ of hearing. This is contained in a spiral chamber, called the *cochlea*, which is imbedded in bone. The cochlea makes about two and a half turns. The inner ear also contains three *semicircular canals* and two small *sacs*. These structures have to do with the sense of balance. Only the cochlea is concerned with hearing.

BASIC ORGAN OF HEARING

The cochlea is about 35 milliliters long. Within it is a tube which follows the windings of the snail-shell-shaped cochlea. This coiled tube is really made up of three adjacent tubes. Each of the three is called a stairway, or *scala* ("stairway," in Latin), because it somewhat suggests a spiral staircase.

The first tube is called the stairway of the vestibule, or the *scala vestibuli*. At its base is the membrane of the oval window, to which the stirrup of the middle ear is attached. Next to the stairway of the vestibule is the middle stairway, or the *scala media*. Finally, there is the stairway of the tympanum, or the *scala tympani*, which has the round window at its base. The scala media contains a liquid called *endolymph*. The scala vestibuli and the scala tympani contain a liquid called *perilymph*. Since the two outer tubes are connected with each other at the tip of the cochlea, it is evident that perilymph extends in a single channel from the oval window to the round window.

The membrane separating the middle tube from the stairway of the tympanum is known as the *basilar membrane*. It is made up of a great number of fine cross fibers. Upon it rest the cells that make up the organ of hearing proper – the so-called *organ of Corti*. Some of the cells, called *hair cells*, have hairlike processes at their tips. These cells are connected to nerve fibers that lead to the brain. Extending over the hairs of the cells like the eaves of a roof is a delicate membrane – the *roof membrane*, which can move freely.

TRANSMISSION OF VIBRATIONS

When vibrations are transmitted to the oval window by way of the stirrup of the middle ear, the fluid in the stairway of the vestibule is alternately pushed inward and then outward again. Since the outer and inner tubes are connected at their tips, the movement of the fluid is transmitted to the round window. When the footplate of the stirrup pushes the oval window membrane inward, the membrane of the round window is moved outward. When the stirrup moves

M. Cambazard

It is important to test a child's hearing on a regular basis, starting when the child is quite young.

back toward the middle chamber, the movement is reversed. As a result of the to-and-fro movement, different parts of the basilar membrane are set to vibrating in turn. The hair cells resting on the vibrating part of the basilar membrane also move in unison, and impulses are generated in the appropriate nerve fibers. These impulses are transmitted to the brain along the *auditory nerve*.

Why does only a part of the basilar membrane vibrate at any one time? The cross fibers of the membrane increase in length. The longer ones are near the top of the spiral, the shorter ones near the bottom. Their rates of vibration depend upon their length. When a vibration of a given frequency – say, 1,500 hertz is transmitted, only that part of the basilar membrane that has the same vibration rate will respond. This is called *sympathetic resonance*.

SOUNDS

The sounds that are transmitted by the ear may be divided into two classes – *tones* and noise. Any sound having a fairly well-marked pitch is classified as a tone. *Pitch* is the quality of sound that enables us to classify it as higher or lower than another sound. Only if differences in pitch are clearly indicated do we refer to sounds as tones rather than as mere noise. It is true that one type of noise – a rumble, say – may be lower than another – a rattle – but the difference between their sounds is not nearly so well defined as the difference between a C and D on a musical instrument.

Sounds have the property of direction. They seem to come from somewhere. In certain cases they appear to come from the direction in which the vibrations are actually set up. But in many everyday situations the source of the sound may be a baffling mystery to the listener. A common example is the difficulty one has in locating a squeak or other noise that develops in an automobile. Many times the source of the noise cannot be discovered by listening. It may be necessary to determine the frequency range of the sound and then to test all possible sources of the squeak to see which one produces vibrations within this range.

Often sounds appear to come from a plausible source (that is, from the place where we could expect them to arise), even though actually they arise elsewhere. This is one of the factors in ventriloquism. If the ventriloquist's dummy moves its lips while the lips of the ventriloquist remain motionless, the plausible source of sound would be the dummy. Therefore to us it seems that the dummy is talking and the ventriloquist is silent, even though the actual source of the sound is obvious enough.

Sound movies and public-address systems involve ventriloquistic principles. When a movie is shown on a screen, the sound source may be located just behind the screen. Yet the sounds seem to come from a variety of plausible sources. Of course this is also true of sound effects on the radio and TV.

When loud-speakers are distributed throughout a hall to transmit the voice of a speaker on a platform, the sounds you hear may come mainly from a place beside you or even behind you. This may prove to be annoying at first. In time, however, the sounds will appear to come from the plausible source – that is, from the speaker.

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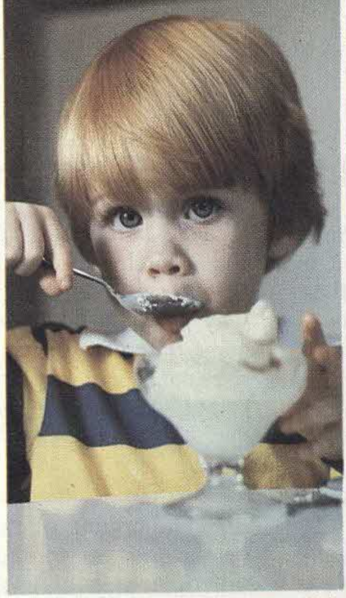


Dennis Hallinan/Alpha

Joan Menschenfreund

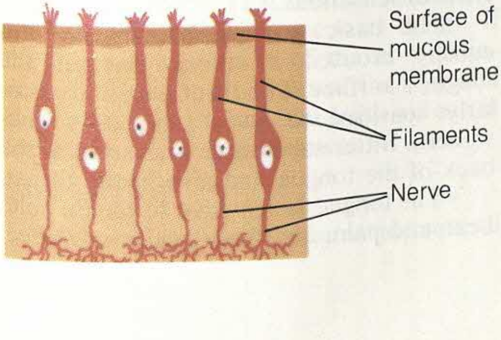
SMELL, TASTE, AND TOUCH

Information comes to people not just through the eyes and ears but also in the forms of smells, tastes, pressures, temperatures, and sensations within the body. Various specialized sense organs pick up these stimuli and pass them along to the central nervous system for processing.

SMELL

The organs of smell are located in the mucous membrane of the uppermost part of the nasal passages, away from the direct path of the stream of air drawn in through the nostrils. The cells involved in smell – the *olfactory cells* – are embedded in the mucous membrane. A long filament of protoplasm leads from each cell to the surface of the mucous membrane. Tiny hairs project above this surface from the filament. A nerve – the *olfactory nerve* – leads from the other end of the cell through a tiny aperture in the floor of the skull to the olfactory lobe of the brain. The surface of the mucous membrane in the olfactory area is bathed in fluid. The particles that are to be smelled must be dissolved in this fluid before the olfactory cells can be stimulated.

Close-up of the cells involved in smell. Note the little hairs projecting above the mucous-membrane surface.



We pointed out that the currents of air drawn in from the nostrils do not pass directly through the olfactory area. However, particles of the odor-releasing substance are carried upward to the area by eddies that arise as the currents of cold air from the outside meet the warm air already in the nasal passages. If we want to sharpen the sense of smell as we become aware of a faint odor, we sniff vigorously. This causes a reinforced stream of cold air to penetrate the nasal passages. The upward currents become stronger, and more molecules of the odorous substance come in contact with the olfactory area.

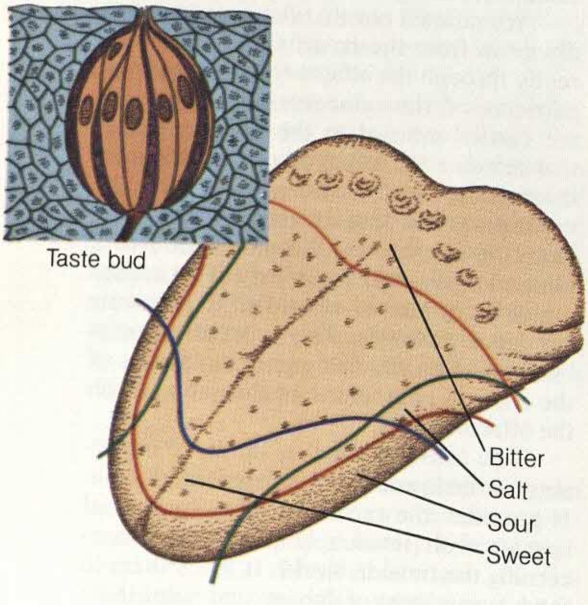
The sense of smell is far more important for the lower animals than it is for man. It provides the members of many animal species with invaluable information concerning the outside world. It leads them to food, warns them of danger, and helps them to select their mates. In man the sense of smell is generally quite rudimentary.

We smell a substance because molecules are constantly thrown off from it in the form of vapor or dust and make their way up the nose. Very small amounts of such vapor or dust can be smelled. If only $1/460,000,000$ of a milligram of a mercaptan, a group of odorous chemicals, is contained in a whiff of air, it can be detected. However, in terms of molecules, the amount is not so small, since it contains some 21,000,000,000 molecules.

If a substance throws off a great many molecules in a short time, it will have a strong smell. This happens, for example, when gasoline fumes arise. On the other hand, a substance will have practically no odor if few molecules are emitted. This is true of most metals. However, when metals are heated to a high temperature, molecules are thrown off in quantity, and there will be a strong odor. The strength of the smell sensation does not always depend on the number of molecules a substance releases.

The sense of smell is a quickly adapting process. This means that when one is exposed to an odoriferous, or odor-producing, substance for a short time, he finds the smell much less noticeable than at first, or he may not even notice it any more. That is why people who have been in a room for some time are surprised when a newcomer complains, say, of the odor of stale tobacco smoke. They have become so adapted to the odor that for them it does not exist.

Taste sensations to which the different surfaces of the tongue are sensitive. A taste bud is shown at the upper left.



TASTE

The organs of taste are found chiefly on the tongue, though there are a few in other places, such as the soft palate and the epiglottis. The receptive structures for taste are called *taste buds*. They consist of bundles of cells, which open upon the surface of the tongue or other area. The 10,000 or so taste buds are located primarily on the upper surface and along the edges of the tongue.

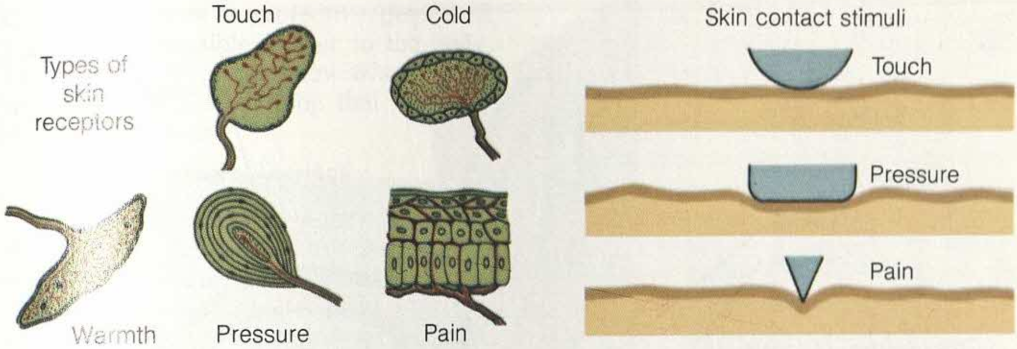
Taste bud cells have tufts of tiny hairs at the openings on the tongue surface. The other ends of the cells are connected to nerve fibers leading to the brain.

Only substances which are water- or fat-soluble can affect the taste buds. Substances in solution stimulate the cells through the hairs. It is important to note that unless a substance is dissolved in the mouth, it cannot be tasted. If you put a piece of lump sugar on your tongue, you will taste it only when it starts to dissolve. Ordinarily the saliva in the mouth dissolves foods sufficiently so that they can arouse the sense of taste.

There are at least four fundamental taste qualities—*sweet, sour, bitter,* and *salty*. Some authorities add a fifth quality—alkaline. All other tastes result from a blending of these four or five and also from combinations of taste qualities with other types of sensations.

The basic taste sensations are not equally aroused in every part of the tongue's surface. The front part is particularly sensitive to sweet and salty substances. Bitter substances are tasted at the back of the tongue and also in the throat.

The tongue is sensitive to touch, cold, heat, and pain, and these sensations affect



Above left: skin receptors for touch, cold, warmth, pressure, and pain. Only the receptor that is responsible for pain has no special structure. Right: how different sensations can be aroused by different types of skin contact.

the sense of taste. Lumpy mashed potatoes do not taste quite the same as smooth mashed potatoes. It makes a difference, as far as taste is concerned, whether a food is dry or moist, soft or hard. An ice cream soda or other soft drink tastes sweeter when it is warm than when it is cold. Thresholds for saltiness, bitterness, sourness, and sweetness vary with temperature, but not equally so.

Sometimes one hardly knows whether one is tasting or smelling a substance. Since the mouth and nose cavities are open to each other, particles derived from food in the mouth may ascend to the nose and stimulate the sense receptors there. This stimulation may be much more vigorous than the stimulation of the taste buds on the tongue. In such a case, taste sensations are mostly sensations of smell.

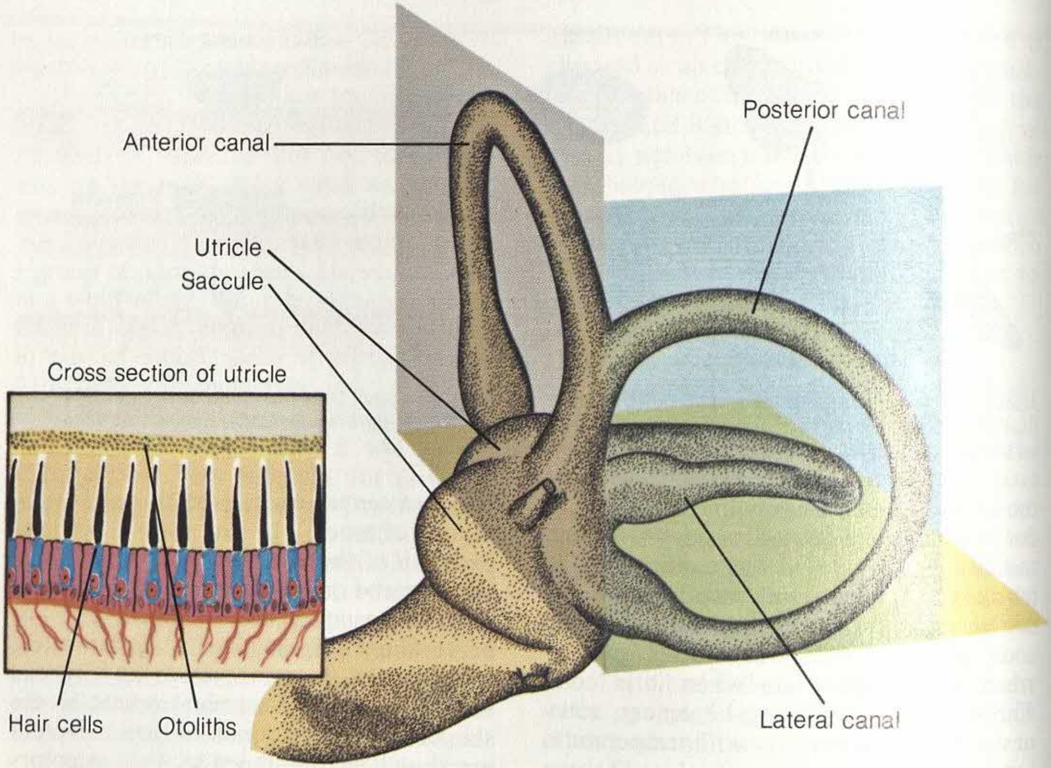
The senses of taste and smell differ greatly in the level of their thresholds. A solution of ethyl alcohol must be 24,000 times more concentrated to reach the taste threshold than to reach the threshold of smell. Only minute quantities of the gases given off from foods are needed to excite the sense of smell. That is why this sense is so often involved when we taste things. If the mucous membrane of the nose is inflamed, the sense receptors of the nose will not be stimulated, and the food we eat at such a time may seem tasteless.

SKIN SENSES

When the skin is stimulated, several different sensations can be aroused – sensations of touch, pressure, heat, cold, and pain. All of these, except the sensation of pain, depend on the presence of specialized sense organs at the end of nerve fibers. The nerve fibers responsible for sensations of pain do not appear to have any special structures at their terminal points in the skin. The different kinds of skin receptors are shown in the diagram. The receptors responsible for touch, pressure, heat, and cold each respond to only one type of stimulus. The nerve endings that register sensations of pain can react to different kinds of stimulation.

The various kinds of sense receptors are not evenly distributed on the skin. It is possible to map out various spots where different types of stimuli take effect in a particular skin area. There are touch spots, heat spots, cold spots, pressure spots. Certain areas of the skin are much more sensitive than others to a given type of stimulation. For example, the finger tips are very sensitive to touch, much more so than the back of the hand. Pain fibers form an extensive network in every area.

Touch-pressure. We can show the different reactions to the sense of touch in different skin areas by applying two points simultaneously to the skin. When the two are very close together, they feel like a single point. As they are gradually placed farther apart, a stage will be reached at which they will just barely be felt as two points. This is called the *two-point thresh-*



The semicircular canals, utricle, and saccule in the ear are concerned with balance. The semicircular canals occupy different places. One is horizontal; the second vertical; and the third, at right angles to the second.

old. The more sensitive to touch a given area of the body surface is, the smaller the two-point threshold will be. It is much smaller on the arm than on the back, and still smaller on the finger tips. The two-point threshold is quite low for the tip of the tongue. When we let this part of the tongue pass over the teeth, a tiny cavity will be felt as a huge pit.

If we lightly touch the skin with a rigid object, such as a matchstick, the sensation of touch will be aroused. If we press more firmly, we will experience a sensation of pressure. This is due to the stimulation of certain sense receptors, called *pacinian* capsules, which are found in the underlying tissues of the skin. As we increase the pressure, the sensation becomes duller and more pervasive. Finally, if the pressure is increased still more, there will be a sensation of pain.

Temperature. If we are to become aware of warmth or cold, something that is at a higher or lower temperature than normal skin temperature – about 25° Celsius – must be applied to the skin. The sensitivity to warmth will extend to a level about 20° above 25°, or 45° Celsius, sensitivity to cold will extend to about 20° below 25°, or 5° Celsius. The sensations aroused by temperatures above 45° Celsius and below 5° Celsius are identical. It is no longer possible to distinguish between heat and cold at such temperatures.

Pain. Pain may be caused by a rigid or sharp object pressed firmly into the skin. However, we pointed out that the nerve endings responsible for sensations of pain can react to different kinds of stimuli. Pain may be aroused by the application of an electric current, by contact with chemicals, or by mechanical effects, such as the cutting or tearing of tissue. It may also result when heat or cold is applied. The sensation of pain is a protective device. It warns us of possible danger to the body. For example, it lets us know when we are getting too near something that is so hot that it can burn us.

INTERNAL SENSES

Balance. Certain senses help us control the reactions of the body to various external stimuli. Among these "control senses" is the sense of balance, or *equilibrium*. It is centered in certain structures of the ear—the semicircular canals and the two sacs within the ear that are known as the *utricle* and the *saccule*.

The three semicircular canals are membranous tubes, filled with fluid. Each leads from the utricle, describes a half circle, and then returns to the utricle. The canals occupy different planes. One is horizontal, another is vertical, and the third is also vertical but at right angles to the second. One end of each canal forms a swelling, called an *ampulla*. This contains receptor structures, from which nerve fibers lead.

The nerve endings in the ampulla are stimulated by movements of fluid in the canal. These movements arise when there is a quick turning motion of the head or of the body as a whole. Each canal is stimulated most strongly when the turning motion is in the same plane as the canal itself. The movement causes a flow of fluid into the ampulla and stimulates the receptor cells there. It produces consciousness of the rotation. It also brings about reflexes that keep the body in proper equilibrium. If the semicircular canals are diseased or destroyed, serious disturbances of balance arise.

The sac called the utricle contains tiny bodies, called *otoliths*, which are attached to the hairs of sensitive hair cells. When the head is tilted, the otoliths, responding to the force of gravity, pull upon the hairs of certain hair cells. As the cells are stimulated, they cause righting reflexes—that is, reflex muscular movements that tend to bring the head and body to a normal position. Motion sickness is probably caused by repeated stimulation of the hair cells in the utricle.

We know little about the functions of the other sac—the saccule, which is considerably smaller than the utricle.

Muscle sense. Another control sense is *kinesthesia*, or muscle sense. It has to do with the control of the muscles. Kinesthesia is based on receptors in the voluntary muscles, tendons, and joints. These receptors register muscular contractions or elongations. They supply information about the state of tension of the muscles and the position of the limbs. The muscle sense helps us control reflex movements. They cause the reflex not to "trigger off" too readily. They help sustain a reflex movement.

The muscle sense helps us coordinate voluntary movements of the muscles. When kinesthetic impulses are lacking, muscular movements are apt to go wide of the mark. A person will often reach in the wrong direction or will bump into things or will go past objects he wishes to grasp. These ill effects vary in extent from one part of a limb to another. They are most marked at the extremities.

The muscle sense helps us judge the weight of objects. This is because kinesthetic impulses relay to the brain the amount of effort that the muscles require to heft an object. Usually the senses of touch and sight are also involved.

OTHER SENSATIONS

Certain sensations supply us with information about conditions in the interior of the body. There are sensations of hunger, thirst, nausea, and fullness of the rectum. The sense of pain may also be experienced from within the body.

There may be acute pain when the large intestine is distended because of gas formation or when a stone obstructs the bile duct, or when circulation in the heart muscle is interrupted. The inner surface of the abdominal wall is sensitive to various types of stimuli that bring about the sensation of pain. Yet apparently the nerve fibers that carry this sensation are not so widely distributed in the inner part of the body as on its outer surface. Almost any one of the internal organs can be cut or crushed or even burned without causing pain.

PERSONALITY

by Gary E. Schwartz

Faces, like fingerprints, are unique. Did you ever wonder how it is possible for us to recognize people? Even a skilled writer probably could not describe all the features that make one face different from another. Yet a very young child – or even an animal, such as a pigeon – can learn to recognize faces. We all take this ability for granted.

We also tell people apart by how they behave. When we talk about someone's personality, we mean the ways in which he or she acts, speaks, thinks, and feels that make that individual different from others.

Like the human face, human personality is very complex. But describing someone's personality in words is somewhat easier than describing his face. If you were asked to describe what a "nice face" looked like, you probably would have a difficult time doing so. But if you were asked to describe a "nice person," you might begin to think about someone who was kind, considerate, friendly, warm, and so forth.

The molding of personality begins in infancy. The mother and father of a child help determine its future character by the way they bring the baby up. Heredity also plays a role in personality.

Suzanne Szasz

There are many words to describe how a person thinks, feels, and acts. Gordon Allport, a U.S. psychologist, found nearly 18,000 English words characterizing differences in people's behavior. And many of us use this information as a basis for describing, or typing, a personality. Hippies, bookworms, conservatives, military types – people are described with such terms.

People have always tried to "type" each other. Actors in early Greek drama wore masks to show the audience whether they played the villain's or the hero's role. In fact, the words "person" and "personality" come from the Latin *persona*, meaning "mask." Today, most television and movie actors do not wear masks. But we can usually tell the "good guys" from the "bad guys" because the two types often differ in appearance as well as in actions.

PERSONALITY THEORY AND CLASSIFICATION

The oldest and simplest method, then, of describing differences in personality was to classify people according to *types*. Such a system is called a *typology*.

A famous example of this method was set forth in Greece about the year 400 B.C. A physician named Hippocrates theorized that there were four fluids, or *humors*, in the body. Corresponding to each humor, he believed, there existed a definite type of personality.

The four humors were blood, yellow bile, black bile, and phlegm. A person in whom all four humors were in perfect balance had a harmonious personality. If a person had too much blood, he was called *sanguine,* or cheerful and optimistic. Someone with too much yellow bile was *choleric,* or irritable and easily angered. Too much black bile made a person *melancholy,* or depressed and pessimistic. An oversupply of phlegm caused a human being to be *phlegmatic,* or slow and unfeeling. Scientists have long since discarded Hippocrates' fluid theory. But the names of the humors, corresponding to these temperaments, have survived and are still useful, to some extent, in describing personality.

Other features of people, such as their faces and physiques, have also been used to classify personality. Today, however, personality theories and classifications may also include factors such as heredity, the environment, intelligence, and emotional needs. Psychology, biology, and sociology are involved in these theories. Because of the complexity of human personality, present-day theories are often very different from one another. Psychologists vary in their ideas about what is most important in determining personality.

For example, some psychologists believe that only a person's outward, or observed, behavior is important. They tend to think that most people, if not all, are basically alike.

At the opposite extreme are psychologists who regard each human being as a complete individual with his own, unique psychology. To such psychologists, even a person's innermost secrets and wishes are important.

Later in this article, we will discuss some of the factors that psychologists think are important in determining personality.

PERSONALITY MEASUREMENT

To measure, say, a person's height, one uses a ruler. Scientists call height a physical dimension. Length, width, and weight are also physical dimensions. Such dimensions are often easy to measure, if we have the proper instruments.

What are the dimensions of a personality? How can we measure them? Generally, we are not dealing with physical measurements, nor with physical objects.

Also, personality is complex. It is not simply black or white in the sense of a simple typology. Rather, there are many in-between shades of gray. For example, when we say that Sally is "warm," or "friendly," we mean that she behaves warmly more often and in a greater variety of situations than many other people. Psychologists would call social warmth a *dimension* of personality.

Psychologists can measure warmth and other personality dimensions, such as intelligence, honesty, happiness, and so on. They have developed tests, scales, and experimental situations to compare one person with another.

The simplest procedure is to observe what people say and do in real-life situations. All of us do this when we are with other people. We watch and compare their habits, speech, and dress, thus learning much about them.

Then why are we not all experts in personality? There are a number of reasons. First, we cannot observe everybody in all situations. Second, we cannot remember every situation and what happened in it. And, third, we have our own personal opinions about people and events. These opinions make it difficult for us to be scientifically accurate. In other words, our own personalities influence our perceptions of other people.

To make personality observation and measurement an exact science, psychologists collect information under *controlled conditions.* That is, they test and record people's behavior under the same set of conditions. This is the only way they can compare people's personalities accurately.

Let us say, for example, that researchers want to measure children's supposed fear of dogs. They set up a cage with a harmless dog at one end of a long room. Each child, or *subject,* who is part of the experiment enters this room. By measuring the distance by which a child avoids the cage, the researchers can estimate his fear of the dog. The closer he comes, the less afraid he is.

An experimenter then asks a child who does come up to the cage to touch it. Next

Inge Morath—Magnum

The word "personality" comes from a Latin word meaning "mask." Actors used to wear masks to show the roles they were playing. In a sense we are all actors, wearing "masks" to hide our true feelings and thoughts from others. But personality, assumed or real, shows a lot about ourselves: it is a mirror of the mind.

he takes the dog out of the cage and asks the child to touch the animal. The child also tells how afraid he is. He rates himself on a 0–10 scale; 0 means no fear, 10, great fear. In this way, psychologists compare different children in their fear of dogs under identical conditions.

This type of experiment, which measures only a small part of the personality, can be quite accurate (assuming the children are truthful and good judges of their feelings). But it is impractical for testing millions of people in schools, government, businesses, clinics, and the armed forces.

Large-scale personality measurements must use more convenient methods. Here, written tests are important. One example of a written test is the *personality inventory.* The subject answers questions about his life, attitudes, habits, and problems. The questions often call for short and clear-cut answers. The subject may only have to answer "True" or "False." Or he may have to choose one of several answers already given to each question.

Other personality tests are less structured. A subject may be asked about his reactions to drawn patterns or pictures. He may even be requested to draw pictures and write stories. The subject may answer by speaking rather than writing. These kinds of tests are called *projective tests:* the subject throws, or projects, his feelings and attitudes onto the persons and objects he sees or discusses.

There are other kinds of psychological examinations and measurements, conducted by interview, in mental clinics, and in make-believe situations that the subjects, however, think are real.

Unlike many tests you have taken, there are no right and wrong answers in personality tests. Only the truth is important. But many people knowingly lie in these tests, because they are afraid to reveal themselves. Or they try to give answers they think the examiners will like, especially if they want to get a job or to leave a prison or a clinic.

Psychological testers know this happens, and they have ways of finding out whether subjects in a test are lying. In addition, the fact that a person lies, and the kinds of lies he tells, are important in studying his personality.

PERSONALITY INVENTORIES

A personality inventory usually consists of a number of smaller tests, or subtests, to get as complete a profile of various personality dimensions as possible. Special training is needed for making and interpreting these tests. Complicated mathematics is often applied to analyze test results.

A familiar inventory is the intelligence test. Have you ever taken one in school? This test is supposed to measure your natural, or inborn, mental ability. But, like most tests, it is not "pure"—information you may have learned in school or from outside reading and your experiences influences your score on an intelligence test.

Another important test is the Minneso-

1. I have certainly had more than my share of things to worry about.
2. I think that I feel more intensely than other people do.
3. I have never done anything dangerous for the thrill of it.
4. I think nearly everyone would tell a lie to keep out of trouble.
5. I am happy most of the time.
6. I tend to be on my guard with people who are somewhat more friendly than I had expected.
7. My mother or father often made me obey even when I thought that it was unreasonable.
8. I feel uneasy indoors.
9. I refuse to play some games because I am not good at them.
10. I find it hard to keep my mind on a task or job.

Sample of the questions used in the MMPI, or Minnesota Multiphasic Personality Inventory. The test taker answers all kinds of questions about his life situation, feelings, and thoughts. From these tests, psychologists may then judge whether the test taker might be mentally ill or not.

MMPI

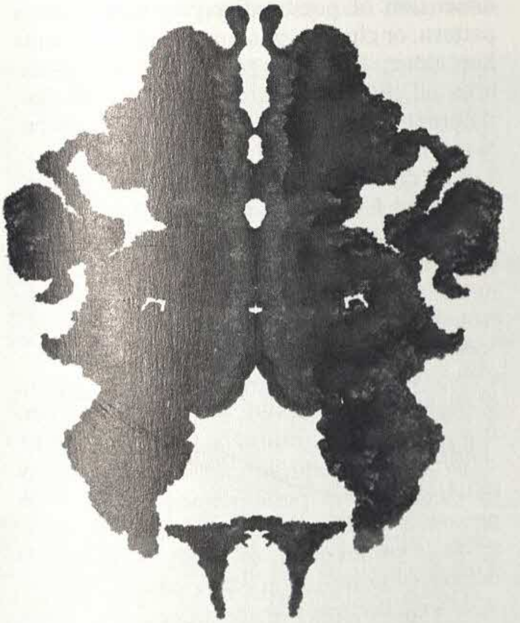


Fig. 1. What do you see? Does the inkblot suggest a bat or insect? There is no correct answer, only a hint as to your personality.

ta Multiphasic Personality Inventory, or MMPI. This is primarily used in the diagnosis of mental illness. After studying the answers to thousands of questions, psychologists have included 550 true-or-false questions in the test. Among the MMPI's subtests is a scale measuring to what extent subjects are lying on the test.

The MMPI is an important research tool also. It has been estimated that over one hundred new tests, using different combinations of the original MMPI items, have been developed to measure other personality dimensions.

PROJECTIVE TESTS

If I asked you to make up a story about a man in the city, what would you write? Not surprisingly, different people would write different stories. One might write about the man's search for friends. Another might write about the man's pleasure in exploring the stores. A third person might write about the man's depression at not finding work. In each case, the person has projected his own personality into the story. Psychologists use projective tests to measure this activity.

The most famous projective test is the Rorschach inkblot test. Originally, a symmetrical blot was made by pouring ink on a sheet of paper, which was then folded in half and pressed together. A whole series of such inkblots has been standardized and printed on cards. An example is shown in Figure 1. When you look at this blot, what do you see? Like any inkblot, it forms a vague pattern that could look like almost anything. Some people see a bird in flight; others see a savage face, a tree, or something else. Psychologists have found that by analyzing what a person sees in the blots it is possible to tell much about that person's personality. However, special training is needed to score and interpret the results of Rorschach tests.

Another important projective test is the TAT, or Thematic Apperception Test, developed by a U.S. psychologist, Henry Murray. Subjects commonly view a series

Harvard Univ. Press

Your interpretation of this picture—part of the Thematic Apperception Test—tells something about your personality.

of 10 to 19 standard pictures. The situation shown in each picture is not obvious. In one, for example, a woman simply stands in the doorway of a furnished room.

Each subject is asked to make up a story, or theme, for each picture. He tells what kind of situation the picture represents and what it means to him. Like the Rorschach, the TAT requires special training for interpreting the results.

SOME DIMENSIONS OF PERSONALITY

If we could measure a person in each dimension of personality, we would get a pattern, or cluster, of scores that represents him alone. However, no single test measures all the possible dimensions. Rather, different tests measure different dimensions, depending on the purpose of the test. Let us consider a few of these dimensions.

Hans Eysenck, a German-English psychologist, has chosen two dimensions of personality that he considers to be very important. One is called introversion-extroversion; the other, emotional stability.

The *introversion-extroversion* dimension describes the degree to which a person is inward and reserved, or introverted, versus outward and outgoing, or extroverted.

Emotional stability is related to how much anxiety a person normally feels. A person who is low in emotional stability tends to be anxious, or easily worried. He depends too much on other people for help and is easily upset or frustrated.

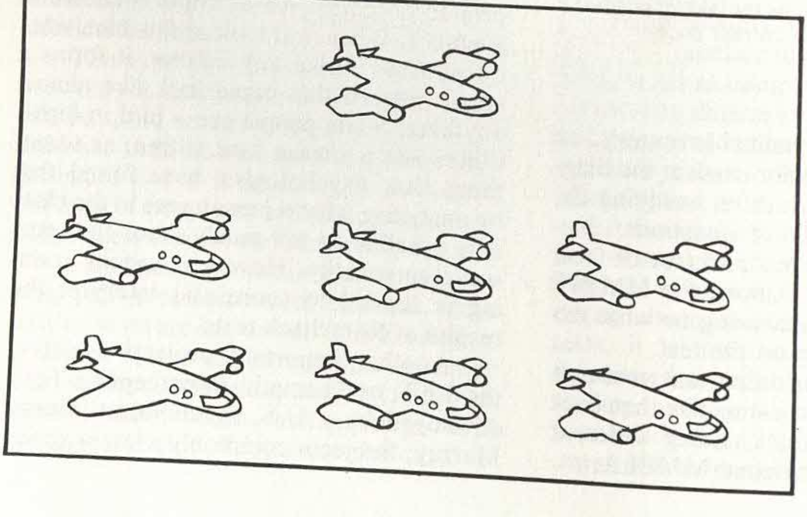


Fig. 2. Sample of Matching Familiar Figures Test. It is designed to measure how impulsive or reflective you are. Try to find which plane in the lower group is exactly like the plane shown at the top of the picture.

Kagan, Pearson & Welch, "Modifiability of an Impulsive Tempo," *Jour. Ed. Psych*, 1966

An emotionally stable person is just the opposite—calm and confident. Such a person, for example, is much less disturbed by noise than an unstable person is. This is the sort of individual who might well say that he can study with a radio on and does not mind interruptions.

Related to emotional stability is the feeling we have concerning the control of our lives. Do we control our own lives ("internal control"), or are we "run" by other people and outside forces ("external control")?

There is a personality test that measures this dimension of *internal-vs.-external control.* People who rate high in internal control feel independent and often act freely. Persons rating low in internal control tend not to feel free to say and do what they really like. Internal-control people are better able to manage themselves. For example, they give up smoking cigarettes more easily than external-control individuals.

In addition to feelings about how they relate to others and about how they control their own lives, people have *needs.* According to Henry Murray, people need to love and be loved, to avoid being hurt, to care

Suzanne Szasz

What do these children see? Our personality determines how we react to stimuli. These children are responding differently to the same situation: some are laughing, others are almost crying.

NYPL—Picture Collection

UPI

UPI

NYPL—Picture Collection

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UPI

Do you think you can tell the personalities and the jobs of people just by the way they look? For example, could you guess why the people in the photographs above are famous? They are an actress, poet, scientist, millionaire, labor leader, and even a murderer. Even if you may recognize some of the persons, try to judge from their appearances. The answers are on page 298.

for and help others, and so on. But they differ in the strength of these needs.

With the TAT, described earlier, psychologists can measure people's needs. For example, the TAT can measure the degree to which a person has the need to achieve.

Another dimension of personality is called *impulsivity-reflectivity*. Look at Figure 2. Try to find the airplane from below that matches exactly the airplane at the top. People differ in the speed with which they do this Matching Familiar Figures Test. Impulsive people tend to act quickly, without thinking. Thus they make mistakes. Reflective people tend to act slowly, carefully thinking things through.

So far we have considered those dimensions related to how people regard themselves, other people, and various life situations. But how about even more basic matters, such as the way we see, hear, and feel different things?

People, psychologists have found, often respond differently to a *sensory stimulus*. A sensory stimulus is something that causes one or more of our sense organs to react. The *augmenter-reducer* dimension indicates how people react to the intensity of a stimulus. Some people, called *augmenters*, respond more and more strongly as a stimulus becomes more intense. Other people, called *reducers*, respond less strongly as a stimulus becomes stronger. High reducers tend to stand pain better than augmenters do. Pain-killing drugs, such as aspirin, work better for augmenters. These drugs reduce the augmenters' reaction to pain.

After reading about the various personality dimensions, you may wonder, which is it better to be? An introvert or an extrovert? Impulsive or reflective? An augmenter or a reducer?

These are difficult questions but, in general, the answers depend on what a person wants to do. If you want to be a writer, it is often better to be an introvert. If you want to be an actor or politician, it is better to be an extrovert. If you must make decisions on which people's lives depend, it is usually better to be reflective rather than impulsive. In dangerous jobs and sports where you may be hurt, it is an advantage to be a reducer.

However, people who show extremes of behavior may reflect an abnormal personality. This, in turn, may indicate mental illness. Even if most people usually consider that behavior to be "good," it may be abnormal—for example, a person who gives or demands much too much love.

DEVELOPMENT OF PERSONALITY

Where does personality come from? Is it inherited? Or is it determined by a person's experiences in life, and his interactions with other people? Research suggests that both heredity and environment play important roles.

Every mother knows that babies differ from one another from the time of birth. These differences seem to be due to heredity, but such factors as the mother's nourishment while she carried the child before birth may also be important.

An obvious biological difference exists between boys and girls. Later, as children grow and develop, sex differences become stronger. Certain glands called endocrines have different physical effects on boys than on girls. These effects, in turn, produce different psychological experiences.

But male-female differences in personality are not due solely to biology. The environment is equally important. Society tends to treat boys and girls differently from an early age. Mothers and fathers, for example, often give boys trains to play with, and give girls dolls to play with.

Many personality theorists emphasize the importance of early childhood experiences in the development of the personality. The founder of psychoanalysis, Sigmund Freud, held that childhood experiences determine the adult personality. Furthermore, he suggested that if a child were deprived of his mother's love at an early stage, for example, that child might develop a personality disorder.

Social and medical factors affect personality as well, both positively and negatively. Poverty, hunger, disease, pain, and violence may stunt the personality. Certain diseases can cause brain damage.

Suzanne Szasz

Children have long been conditioned—through toys, among other things—for a particular sex role in society.

There is frequent disagreement among experts on the relative importance of heredity and environmental factors in shaping personality. The thing to remember is that neither heredity nor environment alone is responsible—both play important roles.

ABNORMAL PERSONALITY

At times, all of us do things that may be inappropriate and ineffective. For example, did you ever get angry at a friend or relative for something he actually did not do? Or were you ever afraid of something that really could not hurt you? On the other hand, some people characteristically act inappropriately to such a degree that we would consider their personality abnormal and describe them as mentally ill.

The term *mental illness* comes from the medical concept of disease. This concept holds that a physical agent, such as a germ or injury to the body, is the underlying cause of the patient's problem. In diagnosing physical illness, a physician tries to determine the cause by looking carefully at the symptoms of the disease. Similarly, a psychiatrist views abnormal personality as a cluster of behavioral symptoms that indicates the nature of the underlying disease.

But, as we have already seen, personality is formed not only through physical factors such as heredity and nutrition. It is also influenced by environmental experiences such as family structure and education. This is why at the present time scientists disagree as to the relative importance of biological versus psychological factors.

Traditionally, scientists have divided abnormal personality into two major categories, the *neuroses* and the *psychoses*. (The singular forms are *neurosis* and *psychosis*.) Have you ever heard the saying, "Everyone is neurotic?" In one sense this is true, because the neuroses are excesses or extremes of normal behavior. It is normal and desirable, for example, to be afraid of automobiles when crossing a street. Although this fear keeps us from hurting ourselves, it does not keep us from actually crossing streets and using automobiles. Some people, however, have such extreme fear of cars that they may be unable to cross a street, or leave their house or even think about cars. These people are said to have a *phobia*. They often require professional treatment. Other emotions, such as anxiety or depression, when extreme, may also be central elements of neuroses.

In addition, excessive behavioral patterns, called *obsessions* and *compulsions*, may constitute a neurosis. For example, some people are sloppy; others are neat and tidy. If this tidiness, however, is carried to an extreme—so that every object in the person's desk or entire house must be exactly in the same spot at all times—then the person may be said to be suffering from a *compulsive neurosis*.

Answers to picture game on page 296: (1) Scientist (Marie Curie); (2) Labor Leader (John L. Lewis); (3) Murderer (Ruth Snyder); (4) Poet (T. S. Eliot); (5) Actress (Maragaret Rutherford); (6) Millionaire (Howard Hughes).

In psychoses, unlike neuroses, the individual has difficulty in perceiving reality correctly. Again, many of the symptoms are extremes of behavior that everyone has experienced at one time or another. For example, did you ever think that someone did not like you, when in fact this was not the case? Some individuals, called *paranoid schizophrenics*, make this mistake to such a degree that they may feel that everyone does not like them.

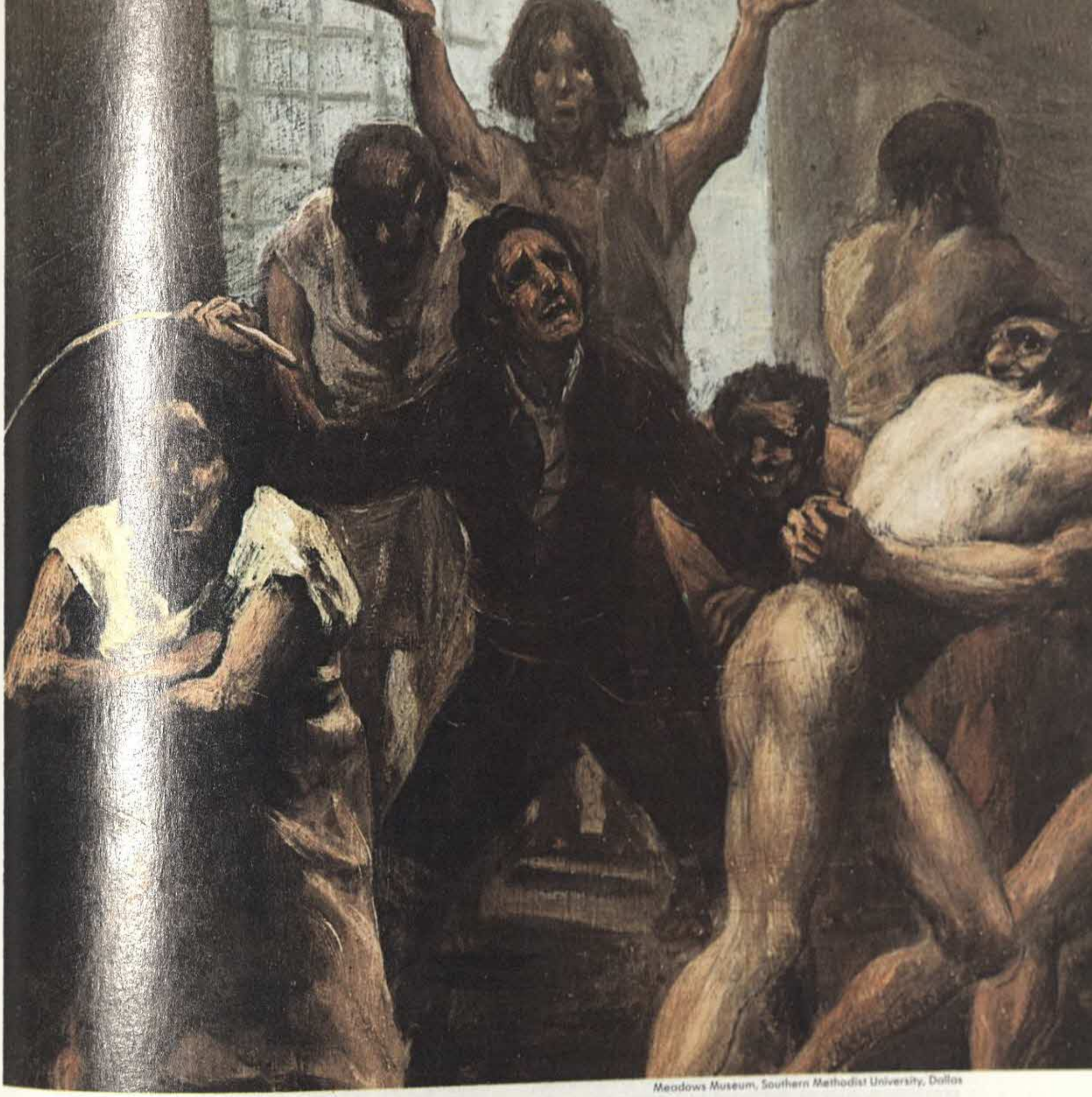
Besides having such delusions, psychotic individuals may shift mood in extreme and inappropriate fashion, or see and hear things that are not there. Or they may withdraw totally from reality and lie motionless in a state of *catatonia*.

Psychotic disorders represent the most extreme form of mental illness. Interestingly, they show the strongest evidence of genetic and biochemical origins.

Our outline of abnormal personality would be incomplete without at least a brief mention of *character* and *psychosomatic disorders*. If an individual appears to have little guilt or anxiety and continually performs antisocial acts, he may be considered to have a character disorder. Like the neuroses and psychoses, these disorders develop for a number of reasons. A child may be a delinquent, for example, because that behavior is standard in his upbringing. Or because of mild brain damage the child may tend to act on impulse and be less affected by punishment.

Have you ever had a stomachache when you were upset? Our bodies react to stress. Extreme, prolonged stress may produce injury to the body. When a person develops a medical or physiological problem that does not have a physical cause, but rather a psychological one, he is said to have a psychosomatic disorder or disease.

Some research suggests that personality is related to these disorders. A person with excessive, pent-up anger may develop high blood pressure. A person with strong needs for love and affection may, in the face of prolonged stress, develop stomach ulcers. In this area, however, as in many aspects of abnormal personality, there are still more questions than answers.



Meadows Museum, Southern Methodist University, Dallas

Emotions out of balance: detail from the painting *The Madhouse*, by the Spanish artist Francisco Goya.

THE EMOTIONS

by Gary E. Schwartz

A child giggles with glee as the funny-faced clown trips over a bucket of water. We say this child is happy. A woman screams with terror when a large dog leaps at her. We say she is afraid. A man yells at the umpire for calling "Strike two!" Then he shouts "Hurrah!" as the next pitch is hit out of the ball park. We say this man is first angry, then very happy. Each of these people is feeling and expressing an emotion.

Everyone knows something about the emotions. A day doesn't pass without our feeling emotions and observing them in others. At some moments we may not feel

Ronald A. Wilford

Some people can convey "feeling states" very well. This famous mime can show joy, sorrow, anger, and fear without saying a word.

any particular emotion. At other times we may experience combinations of them, such as happiness in winning a prize and sadness for a friend who did not.

It has been said that everyone is an expert on the emotions. There is some truth in this. We all experience emotions, and these experiences are private. The only person who really knows what his emotions feel like is that person himself. Of course, we can guess or infer what another person is feeling, as we do when we see a child laughing at a clown. Or a person can tell us, "I am happy now," But we cannot directly experience his happiness. What we can do is understand what happiness feels like for us, and then we can experience happiness for him.

Mankind has long been fascinated by the study of human emotions. We can find discussions of the emotions in religions, medicine, the arts—in almost every human endeavor. But it has only been in the twentieth century that serious scientific investigation of the emotions has been conducted. This research has provided some understanding of what causes emotions; how they develop; what purpose they serve; and how we can, and do, control them. We now have some scientific basis for understanding how we experience and interpret our own emotions, and how we can tell what another person is feeling. We also understand how the emotions can become unbalanced and lead to mental disorders. Research has uncovered ways of treating these disorders. But before we can begin to understand what the research has shown, we must first try to clarify what we mean when we talk about emotions.

WHAT IS AN EMOTION?

First, and foremost, an emotion is a conscious experience. Joy, sorrow, fear, and hate are good examples of conscious experiences that are called emotions. However, not all experiences, or "feeling states," are classified as emotions. For example, we would not consider hunger or thirst an emotion. Similarly we would not call the sensation of pain or cold an emotion.

Then by what rule or procedure do we label our experiences as emotions? This is one of the most basic and most difficult questions in the study of the emotions, and one that has yet to be fully answered. A partial answer is to indicate not what emotions are, but what they are not. Generally speaking, we do not use the word emotion to describe feelings associated with, or caused by, specific localized parts of our body. The sensations of smell, taste, coldness and so forth fall into this category. We can tell that ice cream tastes sweet or that our hands are cold. But it is almost impossible to describe in words what an emotion feels like, or from where the feeling comes. For example, when you feel happy, where do you feel it?

It is important to remember that the feeling state is an important component of the emotions, and that we learn to label these feeling states with words referring to emotions.

Usually, emotion is more than just a feeling state. It also involves (1) bodily processes and (2) action or behavior. Bodily processes are primarily controlled by the autonomic nervous system. They include changes in physiological responses such as heart rate, blood pressure, breathing, and sweating.

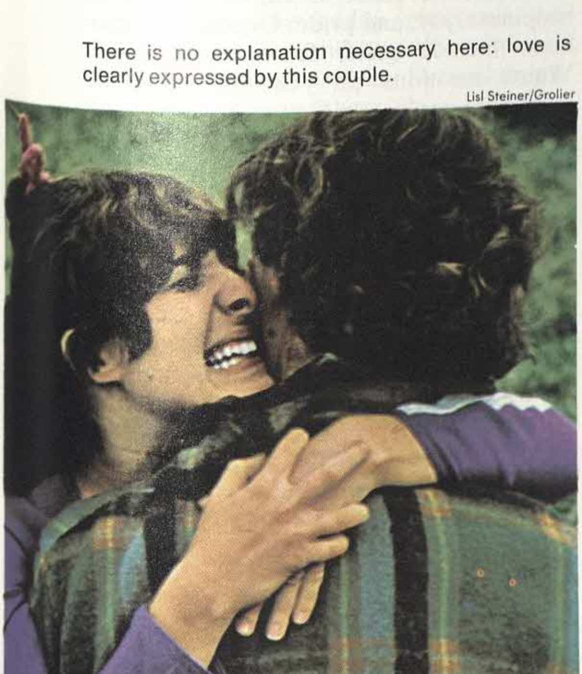
Have you ever been so excited that you felt your heart throb or felt sweat on the palms of your hands? These changes in bodily processes are related to experiencing emotions. They indicate that you are experiencing an emotion. If we notice such changes in someone else, we may infer that he is experiencing an emotion. For example, when it is pointed out to a boy that he is wearing two different-color socks, he may blush because of the increased blood flow to his face. This bodily change tells us that the boy is embarassed.

Emotions may also change our behavior, or the way we act. These changes may be mental or physical. For example, when we are afraid, we may think of things that can harm us, or we may act to avoid what frightens us (for example, we may run away). Activities such as thinking, talking, or moving our muscles as we run are controlled by the central nervous system. Thus both the central and autonomic nervous systems are involved in the effects of emotions.

In summary, we can say that the emotions are feeling states associated with particular bodily processes and specific actions or behaviors. The relationship between what we feel, how our body reacts, and what we do will become clearer as we consider some basic characteristics of emotions and discuss the different kinds of emotions themselves.

There is no explanation necessary here: love is clearly expressed by this couple.

Lisl Steiner/Grolier



CHARACTERISTICS OF EMOTIONS

One of the basic characteristics of an emotional state is intensity. For example, the emotion of anger ranges from slight annoyance to violent rage. Love ranges from casual affection to the most powerful of passions. Generally speaking, the more intense our emotions, the more "stirred up" are our bodily processes and the more apt we are to act. For example, if someone gains little pleasure from learning, he is less likely to work at his homework. Therefore he will receive poorer grades in school. In contrast, a person who derives a lot of enjoyment from learning is much more likely to work at his homework, and therefore will do better in school. Here the greater the pleasure, the greater the action—and the greater the reward.

In some cases, however, strong emotions do not result in action. For example, as fear increases, our bodily processes usually increase (our heart rate may speed up and we may breathe faster), but our actions may decrease. Someone who is slightly afraid of snakes may be a little nervous when approaching a harmless garter snake. But he will pick it up if asked to or if need be. In contrast, someone who is extremely afraid of snakes may have violent bodily reactions to them. Not only may be fail to pick up a snake, he may be unable to look at a picture of a snake or even to think about one. A person with such a strong fear of something that is essentially harmless is considered to have a *phobia*.

Some people have developed such strong phobias that they are unable to drive a car, cross a street, or even leave their room. These strong emotions are unhealthy and may require professional treatment. Not all intense emotions, however, are problems. In fact, most strong emotions, including fears, are essential to the survival

Inger MaCabe/Rapho—Guillumette

Control over expression of one's emotions comes with age. The child at left is clearly upset—but what is the woman at the right feeling?

of man or lower animals. It is healthy, appropriate, and absolutely necessary to have a strong fear of walking in front of a fast-moving car. Can you imagine what life would be like without strong emotional reactions to fire, poisons, and other dangers? We would not survive. Emotions, even strong emotions, are very important to our existence. Emotions only become a problem if they lead us to do things we shouldn't or keep us from doing things that we should certainly do.

Because strong emotions arouse our bodily functions, it is important that intense negative emotions do not continue for very long periods of time. Otherwise it is possible that physical damage to the internal organs may occur. An executive under continual stress over the years may develop heart trouble or stomach ulcers. Physical problems produced by psychological causes are called *psychosomatic disorders*. Research on monkeys, rats, and mice demonstrates that even animals can develop psychosomatic disorders if certain stresses continue for a long enough time. Many kinds of psychosomatic disorders can be successfully treated with a combination of surgical and drug procedures as well as by reducing the sources of stress that affect the individual.

You may still wonder: what value do the emotions have? Our emotions hlep us in many ways. They keep us from doing things that will harm us, and they lead us to do things that are important and enjoyable. In a sense, our emotions "drive" us to do or not to do things. This is why the emotions are sometimes considered *drives*.

Our emotions not only help us, but they enable us to help and care for others. When we love someone, we are kind to that person and want him to be happy and successful and protected from harm.

Another basic characteristic of the emotions is their relative pleasantness or unpleasantness. When we think of pleasant emotions, we think of emotions such as happiness, joy, and pride. Unpleasant emotions include grief, fear, and sadness. Which emotions do you find pleasant? Which are unpleasant for you?

Not all emotions are pleasant or unpleasant; some may be neither. For example, what does "surprise" feel like? Sometimes it is pleasant, sometimes it is unpleasant, and sometimes it is neither. You can probably think of some pleasant surprises, some unpleasant ones, and others that are just "surprises." Whether an emotion is pleasant or not depends a great deal on what has happened, what is happening, or what will happen. For example, winning a prize may be a pleasant surprise, but getting punished unexpectedly is usually an unpleasant one.

The great novelist Tolstoy wrote: "Happy families are all alike; every unhappy family is unhappy in its own way." There is something familylike about the different people shown here.

top, left to right: John Ross, Paolo Koch, Carl Frank/Photo Researchers; Michal Heron; Kay Chernush, Image Bank; Bill Binzen.

We now have a basic understanding of what the emotions are: feeling states associated with bodily processes that lead us to act or behave in certain ways. We also know that two basic characteristics of emotions are their intensity and the extent to which they are pleasant or unpleasant.

MEASURING BODILY PROCESSES

Before discussing different kinds of emotions, let us briefly talk about how researchers measure bodily processes, actions and behavior, and how this relates to what we do in our everyday lives when we observe emotions in others.

Bodily processes can be directly measured by means of a *polygraph*. When a polygraph is skillfully used to compare how we react bodily with what we are saying, it is called a "lie detector." Bodily processes can also be measured indirectly. This is what we do when we observe someone blushing. However, we are not always aware what bodily processes we respond to.

Measuring action or behavior is the other way researchers assess the emotions. For example, one measure of fear of snakes is how close a person will go to the snake. Another procedure is to have a person tell how afraid he is, or rate how he feels. In this way, researchers have developed the so-called "fear thermometer" to assess a person's fears. In our everyday living, we do very much the same thing, only not so systematically. We react to what a person does, what he says, how he says it, and how he looks. Is he smiling? Is his voice trembling? We put all these observations together to infer what a person is feeling.

However, we do not always act as we feel. Sometimes we do things that we don't feel like doing. Sometimes we say we feel one way and then we act another. Actors, for example, successfully learn to "make believe" emotions, or learn to hide them. Thus we cannot always tell what a person is feeling by what he says or by what he does.

EMOTIONS AND DRUGS

Researchers know there are many drugs that can alter our bodily processes in such a way as to affect our emotional experiences. One such set of drugs is commonly referred to as *sedatives* or *tranquilizers*. They act to "slow us down" emotionally and make us less responsive. A doctor may prescribe a tranquilizer for someone who is very tense or very anxious and who cannot

I. Lippman

Control of emotional expression is highly valued in some cultures and in some professions. Here a member of the military conveys no emotion as he stands guard.

sleep or function because of his overarousal. Emotional disorders of extreme overarousal are often effectively reduced by such drugs.

Another set of drugs is called *stimulants*. They "perk us up" emotionally and make us more responsive. A common mild stimulant is caffeine, a drug found in most coffees. It is because of its caffeine content that coffee often gives us a "lift," wakes us up, and helps us be more responsive. Some stimulants are very potent and may effectively counteract extreme depression. Under a doctor's care, the use of strong stimulants can be very beneficial.

Other kinds of drugs can also have profound effects on our emotions. These include chemicals found in marijuana, narcotics, and hallucinogenic drugs such as LSD. These drugs may produce unpleasant as well as pleasant feelings. Also they can be very dangerous. Some are strongly addictive, and many can cause various kinds of damage.

POSITIVE AND NEGATIVE EMOTIONS

How many different kinds of emotions do you feel? You may be surprised to find that it is very hard to specify all of them. Not only are emotional feelings hard to describe in words, they are difficult to list. As a result, two people rarely agree on all of them. However, there are a number of basic emotions that most people experience. We will consider some of them here.

When we receive something that we want, or something happens that we like, we usually feel joy or happiness. Joy is a positive and powerful emotion, one for which we all strive. It is natural to want to be happy, and all of us search for happiness. As a general rule, joy occurs when we reach a desired goal or obtain a desired object.

Since people often desire different goals and objects, it is understandable that one person may find joy in repairing an automobile, while another may find joy in solving a math problem. Of course, we often share common goals or interests, and therefore we can experience joy together. This may be in sports, in the arts, in learning, in raising a family, or in just being together.

When we have difficulty in obtaining desired objects or reaching desired goals we experience negative emotions such as anger and grief. When little things get in our way, we experience minor frustrations or tensions. For example, if you are dressing to go out on a date, you may feel frustration when a zipper breaks or a button falls off. The more difficulty you have in reaching a goal, the more frustrated you may feel and the more angry you may become. If you really want something to happen, and you feel it should happen, but someone or something stops it, you may become quite angry.

Whereas positive emotions such as joy are easy to deal with and express, negative emotions such as anger are more difficult to handle and express. Anger in itself is not a bad emotion. Like all emotions, it serves an important function. If a person never got angry when people or things kept him from doing what he wanted or needed to do, he might end up never doing anything at all! Therefore a certain amount of anger is necessary and appropriate, and should be expressed. But, like any emotion, anger can be misused and become a problem. If a person becomes extremely angry over a minor incident and then becomes overly aggressive or violent, this indicates that he has difficulty reacting to frustration and controlling his anger. In general, most of us learn to effectively use and control our anger, for we learn when it is appropriate to be angry and how best to express it.

UNPLEASANT EMOTIONS

If we lose something that we value or desire, we may experience grief. Grief varies in intensity from slight sadness to extreme depression and despair. The more something is valued, the more sadness we experience upon its loss. Grief is not a pleasant emotion, and it may be difficult to handle. If someone we love becomes gravely sick or dies, we may feel very depressed and sad, and these feelings may last a long time. With grief, there may be loss of sleep, loss of appetite, crying, and withdrawal.

It is normal to feel sadness, and it is natural and appropriate to grieve over an important loss. It is only when people cannot get over their sadness, or when they become very depressed over the slightest loss, that grief becomes a problem. As a general rule, emotional disorders occur only when emotional reactions are extreme and out of proportion to the situation that produces them.

Whereas joy, anger, and grief are the primary emotions associated with desired objects and goals, fear is the primary emotion associated with undesired objects and goals. In fear, our reaction is not to approach an object, but to avoid it. As mentioned earlier, fear is an important emotion that helps protect us from harm. Feared things may be dangerous, painful, hideous, or unexpected. If you suddenly hear a friend scream behind you, you may experience fear. But if your friend walks up to you and says, "I'm going to scream now," you probably won't be afraid.

Carnival time! All societies have occasions that provide emotional release. Very often such occasions bring out little-known sides of a person's emotional make-up.

Grolier, N.Y.

I. Lippman

Amusement parks provide an emotional release for their patrons. They give people the chance to enjoy fear: most of the dangers are unreal.

An emotion very similar to fear, both subjectively and physiologically, is anxiety. When we are fearful, however, we usually know what it is that we fear. When we are anxious, we usually do not know what causes our anxiety. Like fear, anxiety serves an important function, for it arouses us, consciously and bodily, to search out potentially harmful events.

Even animals experience some such fears and anxieties. Research shows that monkeys act very frightened when shown a picture of a monkey without a head or a picture containing just the head of a monkey. Research also indicated that some fears are innate or instinctive, while others are learned through experience.

Another general class of emotions is those related to sensory stimulation. The negative emotion of disgust is one that occurs in response to extremely unpleasant stimuli; the bodily reaction of nausea usually results. Human bodies ripped apart in a car accident is an example of something that may cause disgust. In contrast to disgust, many kinds of stimuli cause positive emotions such as delight. Music, paintings, dancing, even tastes and smells can cause pleasant sensations that we would call delight. If something not only delights us, but is funny and makes us laugh, we experience the emotion called humor.

EMOTIONS AND SELF-APPRAISAL

There are large classes of emotions that relate to how we look at and appraise ourselves. One such set of emotions involves feelings of success and failure. When we do something we consider a success, we usually experience positive feelings. If we do something we consider a failure, we may experience negative feelings.

What determines whether something is a success and failure? Two basic factors are involved: the standard that people set for us and the standard that we set for ourselves.

Usually we feel most successful when our performance reaches other people's expectations or standards as well as our own. Sometimes, however, we set our standards so high that we never can do well enough to feel that we have succeeded, even though others tell us we have done well. Or others may set their expectations of us so high that, although we think we have done well, they feel that we should have done better. Fortunately people generally set reasonable goals for themselves with which other people agree. This is why most people feel they can and do succeed.

Related to feelings of success and failure are feelings of pride and shame. We are proud of ourselves when we succeed at things we do, while we may feel varying degrees of shame if we feel we have failed. Did you ever receive a poor grade at school which made you feel so ashamed that you didn't want to tell anyone?

Not only do we feel pride and shame for ourselves; we can feel these emotions for others as well. For example, we may feel pride for a friend if he scores the winning point at a soccer match, while we might feel shame for the same friend if at the last minute he tripped over the ball and lost the game. A common, mild form of shame is embarrassment, and, like shame, we can feel it for ourselves and for others.

If we make a mistake or do something that we feel is morally wrong, or bad, we may feel the emotion of guilt. Guilt is a very unpleasant emotion, one that most people experience as distressing or painful. However, like all emotions, guilt serves an important function, for it helps to keep us acting and behaving in ways that will be helpful, not harmful, to others. Can you imagine a world without guilt? Without guilt, people would be more apt to lie, steal, abuse, or kill for what they wanted. Guilt is the emotion most related to the religious and moral structure of society.

Just as too little guilt can be a problem, so can too much guilt. Some people feel so bad about themselves that they can never be happy; they feel that everything they do is wrong or worthless. For these people, professional treatment may be necessary.

LOVE AND HATE

We have saved as a final set of emotions the two most important emotions pertaining to other people: love and its opposite, hate. Love can be seen everywhere. Yet surprisingly, love has been the subject of less scientific research than other emotions, such as anger and fear. The reason for this may be twofold. First, love is a very complex emotion, difficult to describe and measure. Secondly, unlike many extreme emotions, extreme love is generally not a problem; thus less medical attention has been paid to it.

What is love? This is a complex question and requires a complex answer. Love is an enduring, strong, positive attraction and feeling for another person or thing. But it is more than this. It also involves feelings of caring, protection, excitement, and tenderness. When two people are in love, they feel drawn to one another; they greatly enjoy each other's company; and they may be sexually attracted to one another.

Sometimes it is easier to think in terms of different kinds of love: "puppy" love, romantic love, brotherly love, and so forth. Though they differ in some respects, they share one important characteristic: a strong positive feeling toward another.

Our feelings toward other people are often complex. We may love someone and, at the same time, be angry with him. Or we may love someone, even though we are jealous of him. We might even love someone and, at the same time, hate him for some specific reason.

Hate is a strong negative emotion toward someone, and is due to anger, jealousy, or some other factor. Like love, hate can be a very strong emotion. It can also be very dangerous. The question is often asked, "Is it bad to hate?" The best answer is probably "sometimes yes and sometimes no." Usually hate does not help us; it makes us feel unhappy and makes us do things that may hurt others. However, sometimes it may be necessary to hate and hurt someone in order to protect loved ones.

LEARNING AND DEVELOPING EMOTIONS

How does a person become the emotionally complex person he is? What are the origins of his daily frustrations, his morbid fears, his feelings of love? Is a person born with all his emotions or are they learned? Or do the emotions develop both through maturation and learning?

Research has shown that the emotions do develop and mature from infancy through adulthood, partly as a function of the growth and development of the central and autonomic nervous systems. Some emotional responses are inborn, although they may not appear until the child has reached a certain stage of growth. However, research also shows that many emotional responses are learned through experience. In view of the complex nature of our emotions, it is not surprising that their development should be equally complex.

A newborn baby is a helpless, undeveloped organism that does little more than drink milk, move around a bit, cry when hungry or uncomfortable, and sleep. However, if you startle a baby by sounding a bell or flashing a light, you may cause the baby to cry. The young infant does react to pain, discomfort, or startling stimuli, but his reactions are of a very global, uncontrolled nature. We might say that his emotional life simply consists of degrees of comfort and discomfort.

As the baby grows and develops, he learns to interact with people and things in his environment, and his emotional responses begin to increase in number. By the age of five months, a baby may show signs of both pleasant and unpleasant emotions, including distress and even anger. Delight may clearly be present by the third month, while most signs of love and affection may not until the baby is 10 or 11 months old.

CONDITIONING

In the same way that a child must be able to move his arms and legs before he can learn to walk, the child must physiologically be capable of producing and experiencing particular emotions before these emotions can be modified through learning. Psychologists have found that there are two basic processes by which learning takes place. One kind of learning is called *classical conditioning*. This occurs when one event or stimulus is consistently paired with, or followed by, a reward or punishment. It is through classical conditioning that a child learns to associate his mother's face and voice with happiness and love, for he learns that this person provides food and comfort. Negative emotions are learned in a similar fashion. If a child is bitten or startled several times by a dog, he may learn to associate furry animals with pain or startle and thus develop a fear of furry animals.

The second kind of learning is called *operant conditioning*. This occurs when an individual learns to do things that produce rewards in his environment and learns not to do things that produce punishments. For example, if a mother always attends to her baby when he cries and cuddles him until he is quiet, she may teach him that if he cries he will get attention from mother. Thus, the baby will learn to increase his crying in order to have his mother more.

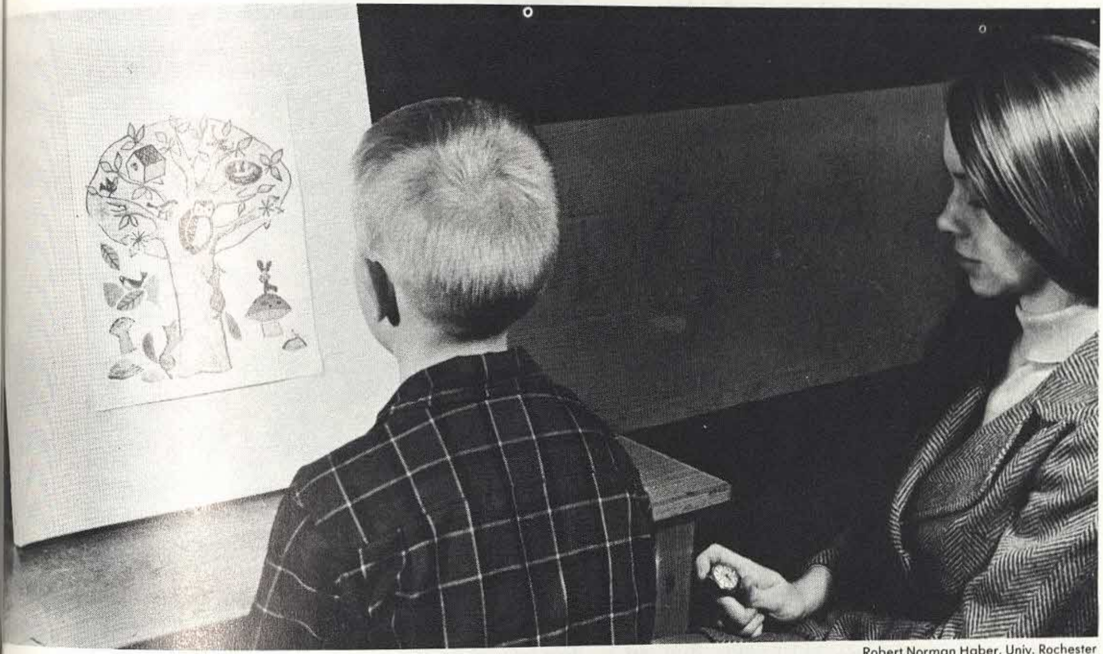
Every day, we grow and have new experiences. We constantly learn by reading, watching television, interacting with other people, and so forth. This learning affects our emotions. Why is it that we learn to like some people and dislike others? If a person is nice to us, cares about us, and tries to do positive things for us, we learn through classical conditioning to associate this person with positive feelings, such as joy, happiness, and friendliness. On the other hand, if a person is mean to us, does not care about us, does not try to do positive things for us, and even deliberately does things to harm us, we learn to associate this person with negative feelings, such as unhappiness, discomfort, and anger.

Usually there are very few people whom we completely like or dislike. This is because there are good points and bad points to every person, and every relationship generally has some combination of both. This is why our feelings about another person may be very complex. Also our feelings may change as we grow and change, as situations change, and as other people grow and change. Did you ever have a friend whom you eventually found that you no longer liked? Or have you ever known someone you initially disliked but later found you liked?

We also continue to learn through operant conditioning. For example, if we tell a few jokes to a person, and that person responds to our jokes with laughter, we will learn that telling jokes to this person is fun. Therefore we will be more humorous in his presence. On the other hand, we may tell a few jokes to someone who does not like jokes or cannot at that time enjoy them. He may respond negatively to our jokes by not laughing or by frowning. Thus we learn to be less humorous with this person. Learning to control our emotions with different people and in different places is natural and necessary.

Besides being affected by maturation and learning, our emotions are affected by the level of our bodily processes. For example, when we are hungry, the sight of an ice-cream sundae may produce strong, positive emotions of desire and delight. However, when we are not hungry, or have overeaten and are very full, the sight of an ice-cream sundae may no longer produce a positive emotion. Instead it may produce disgust and nausea.

In other words, how we react emotionally depends not only on maturation and learning but on how we feel at that moment. A child may normally giggle with glee as he watches a clown. But if the child has been scolded or doesn't feel well, he may not find the clown's performance amusing. Similarly your emotional responses to various stimuli will vary, depending on what factors influence you at the time.



Robert Norman Haber, Univ. Rochester

Many children can briefly retain images "photographically." Here, a boy is being tested for "eidetic memory." After he has examined the picture, it is removed. He then tells the experimenter what he sees on the blank background.

MEMORY

by T. K. Landauer

It is difficult to imagine what life would be like without memory. The meanings of thousands of everyday perceptions, the bases for the decisions we make, and the roots of our habits and skills are to be found in our past experiences, which are brought into the present by memory.

Memory can be defined as the capacity to keep information available for later use. It includes not only "remembering" things like arthmetic or historical facts, but also involves any change in the way an animal typically behaves. Memory is involved when a rat gives up eating grain because he has sniffed something suspicious in the grain pile. Memory is also involved when a six-year-old child learns to swing a baseball bat.

Memory exists not only in humans and animals but also in some physical objects and machines. Computers, for example, contain devices for storing data for later use. It is interesting to compare the memory-storage capacity of a computer with that of a human being. The instant-access memory of a large computer may hold up to 100,000 "words"—strings of alphabetic or numerical characters—ready for instant use. An average U.S. teenager probably recognizes the meaning of about 100,000 words of English. However, this is but a fraction of the total amount of information which the teenager has stored. Consider, for example, the number of faces and places that the teenager can recognize on sight.

The use of words is the basis of the advanced problem-solving intelligence of human beings. A large part of a person's memory is in terms of words and combinations of words. But while language greatly expands the number and kind of things a person can remember, it also requires a huge memory capacity. It may well be this capacity that distinguishes humans, setting them apart from other animals.

THREE ASPECTS

The process of memory can be divided into three aspects. The initial storage of new information is called *learning.* Next there is *retention:* keeping the new information available. A failure of retention is called *forgetting:* the loss of the new information over a period of time. Finally there is the process by which stored information is utilized or *retrieved.* In this article we will discuss some of the major aspects of learning, retention and forgetting, and retrieval of memories. We will also consider the physical basis of memory storage in animals, and how a person can make his or her memory work most effectively.

LEARNING PROCESSES

The essence of learning is that, afterward, an organism is able to react in a new way to an old situation. This change in an animal can be produced in several different ways. These include:

Adaptation. When a stimulus that produces a natural response is presented over and over again, the organism's reaction becomes less and less vigorous. For example, the sound of a gun being fired would normally startle a person. But if he hears the gunfire a second, third, fourth, or tenth time, he ceases to be startled by the noise: he has become adapted in his response. This illustrates how experience can change the way in which an animal behaves; involved is a simple form of memory. This kind of learning is only temporary. A short rest will usually restore the effectiveness of the stimulus.

Imprinting. One special kind of memory formation occurs in some animals very early in life, as the following example illustrates. A week-old duckling will follow its mother, and only its own mother, everywhere. But a 12-hour-old duckling will follow anything that moves, even a block of wood pulled along. A duckling learns to follow the first thing that passes it at the right speed during a particular *critical period* in its development—about one day of age. Whatever it follows during this period, it will always follow. Luckily for the duck, it is usually its mother. Because this kind of learning occurs rapidly and is hard to undo, it has been called imprinting.

Harold M. Lambert—Frederic Lewis

As she practices the movements needed to ride a bike, this girl will become more and more proficient. Once she has learned this skill, she will remember it for many years.

Classical conditioning. When two stimuli are repeatedly encountered together, the first one may, if circumstances are right, take on some of the properties of the second. The 19th century Russian physiologist, Ivan Pavlov, taught a dog to salivate at the sound of a bell, by making an effective stimulus for the salivation reflex—food in the mouth—occur repeatedly right after the bell. This kind of conditioning works only if the stimulus pairing occurs in the right way. The new stimulus must come before the originally effective one, and it is usually best if they are separated by exactly one-half second, neither more nor less.

Trial-and-error learning, or operant conditioning. Another way of inducing a change in typical behavior is to reward an animal—that is, to make some special event follow when it behaves in a certain manner. This kind of training is familiar to everyone who has rewarded a dog by patting it on the head when it performs a trick. As in other forms of conditioning, very specific arrangements are essential to efficient learning. For example, if the reward is delayed by more than a few seconds, learning will occur very slowly.

Motor learning. As people practice a new movement skill, their proficiency increases. The movement becomes smoother and more error-free. Spacing of practice is important in this and many other kinds of learning. A person learns to throw a basketball, play a violin, or operate a typewriter much more efficiently if practice is divided into many short periods. The same amount of practice done all at once is not as effective.

Stimulus-recognition memory. A very impressive form of memory is the ability to recognize familiar things. Shown several hundred randomly selected photographs over a period of several hours, a person is able to distinguish them from similarly selected new photographs with almost perfect accuracy. One special and quite rare extension of this ability is *eidetic imagery,* or so-called photographic memory. Minutes after seeing a picture, a person with eidetic imagery can stare at a blank sheet and read off the images almost as if he were actually looking at the picture again. Eidetic imagery seems to be more common in children than in adults. Scientists have speculated that it may be a natural ability that vanishes as a person learns to read and begins to use words instead of visual images as a basis of memory.

KEL	**2**
POG	**3**
SAV	**6**
GID	**5**
YUK	**4**
MAZ	**9**
ROQ	**8**
FUS	**1**
CER	**7**

Fig. 1. Try to memorize these pairs of nonsense syllables and digits. How many pairs can you remember after studying the list once? Twice? Five or ten times? How many pairs can you remember after 24 hours?

Verbal learning. Since words are so important to people, many laboratory studies of human memory have concentrated on memorization of words and wordlike stimuli. For example, a typical experiment on human learning would have the learner try to memorize the pairs of *nonsense syllables* and digits shown in Figure 1. The object is to learn which digit goes with each syllable. As a person studies such a list over and over, he remembers more and more pairs. Try it.

RETENTION AND FORGETTING

New behavior may or may not last for a long time. Consider the usual fate of a newly encountered 7-digit phone number. After one hearing, the average person will not remember the number permanently, but he will remember it temporarily, for perhaps half a minute. A measure of a person's capacity for this type of memory is called a *memory-span test.* A digit-memory-span test consists of reading longer and longer strings of digits – 4, 5, 6 – until the subject's limit is reached. The limit, or *digit span,* is defined as the length of the longest string that can be remembered, immediately after it is presented, at least half the time; for the average person this is between 6 and 8.

This kind of learning produces what is called *short-term memory.* Things that are close to the memory-span limit are forgotten within seconds or minutes if they are not rehearsed. Even after thorough learning with many practice trials, some forgetting eventually occurs. You practice a list of French vocabulary words over and over again until all of them are mastered. Will you still know them perfectly two days later? You will probably remember only 70 – 80 per cent of the words.

The kind of memory that results from thorough practice is often called *long-term memory,* because forgetting takes days, months, or years, rather than seconds or minutes. One of the earliest studies of long-term memory was carried out by the Ger-

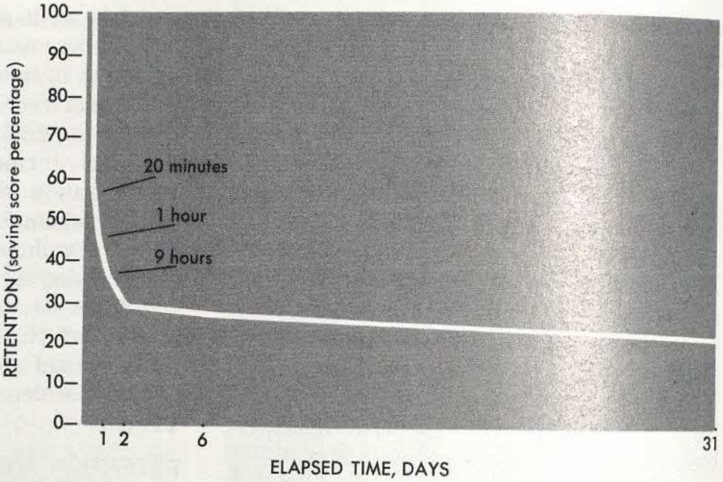


Fig. 2. This retention curve shows that nonsense syllables are forgotten quickly at first and then more slowly as the time since memorization increases. After one hour, for example, the person remembered less than half the syllables. Test yourself, using the syllables in Figure 1 or by preparing your own list.

man psychologist Hermann Ebbinghaus, the inventor of "nonsense syllables." Ebbinghause taught himself hundreds of strings of nonsense syllables (such as bip, fiq, naw, rof, puz . . .). After studying each string until he could recite it perfectly, he waited varying amounts of time and then tested himself by seeing how long it took to learn the same string again. The "forgetting curve" that he obtained is shown in Figure 2. The measure of the amount of material he remembered is in terms of the time saved in relearning as compared with the original time he spent learning the same list. You can see that after just one hour, Ebbinghaus remembered only 44 percent of what he had learned.

These data are often taken as an indictment of memorization in general—if one forgets so fast, what's the use of memorizing something? But there is more to the story. The rate of forgetting depends on how learning is accomplished, on what is learned, on what has been previously learned, and on what happens between learning and remembering. For Ebbinghaus all these factors were about at their worst. His forgetting curve therefore represents one of the most rapid cases of forgetting ever observed.

Rapid forgetting usually occurs if the learner previously memorized a large number of similar things—new and old learning apparently become confused in memory. Ebbinghaus of course had already learned hundreds of such lists. In addition, if one learns minimally—for example, for only a single correct recitation (as Ebbinghaus did)—forgetting is much more rapid than if practice is more thorough. If Ebbinghaus had never learned a nonsense syllable before, and if he had practiced twice as long, he might well have remembered as much as 80 per cent as long as a week later. It is also known that meaningful things, those about which something is known beforehand, are lost much less rapidly than are meaningless things like nonsense syllables.

Scientists currently attribute the major portion of forgetting to something called *interference*. Interference is simply confusion—the fact that a person who has learned two similar things will have trouble keeping them separate. The pairs shown in column A of Figure 3 are highly confusable with those in Column C, while those in Column B are not. If all three lists are learned equally, say to a single correct recitation, A and C will be forgotten much

Fig. 3. The pairs in column A are easily confused with those in column C.

A	B	C
PIK-2	**KEL-1**	**PIC-9**
YUK-4	**GYR-7**	**YOK-6**
MAZ-8	**CEM-5**	**NAZ-3**

Fig. 4.

X G A R
T Z F B

more rapidly than B (test yourself—try memorizing them now and recalling them tomorrow.) Is forgetting due solely to interference? We do not know. It is conceivable that the nervous system can simply lose the physical record of what has been laid down in memory.

RETRIEVAL

Some of the effects of interference do not occur until the person tries to use the remembered material. This can be illustrated in the following way. Eight letters visually arrayed in two rows of four, as shown in Figure 4, are flashed on a screen for a half second or less, and the observer immediately tries to report them. Ordinarily, the average person could not remember more than four or five of them. But if within a second after they disappear he is asked to name only the top four, or only the bottom four letters, he can usually do so perfectly. Apparently all 8 letters have been stored, but the act of retrieving the memory of some destroys the memory of others.

Another interesting aspect of memory retrieval is the fact that a great deal of the information that a person has stored is not immediately available at any one time. One example of this is inherent in the method of measuring memory used by Ebbinghaus, as described earlier. Even when he was able to recall almost nothing from a previously learned list, he could relearn it in at least 20 per cent fewer trials. Apparently, things once learned are never completely forgotten.

Another example of the problem of retrieval is the "tip of the tongue" feeling. Although you are unable to remember a word or a name, you still "know" that you know it. Usually you will remember it if you are given a little help—a list of alternatives from which to choose, or a hint of some kind. Or after a while the word may spontaneously pop into your mind. Often you can correctly report the first letter or length of a word that you "can't remember." This tells us that the information must be there, but the location tags in your mental filing cabinet have been mislaid or are inadequate.

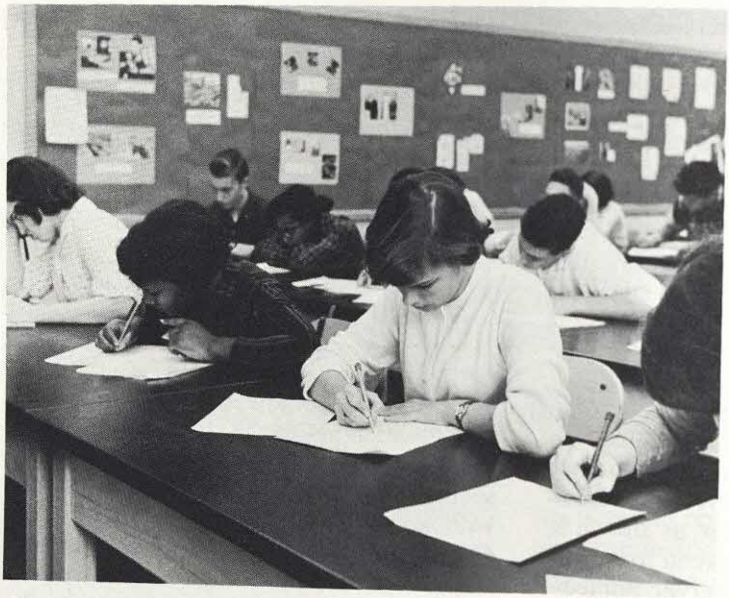
As you can see, a person's knowledge of what he does or does not know is imperfect. An individual usually has a strong feeling of knowing something when he first memorizes it, despite the fact that it will be forgotten rapidly unless he practices. On the other hand, he can fail to recall something that he actually knows. It is particularly hard to recall facts, or to estimate how much you really know, when you are out of the situation in which the learning took place. Thus a great deal of school learning seems to evaporate when you are finished with your last exam and out of school. However, it is lurking in your memory, ready to make itself useful when an appropriate environment for its use is again encountered.

PHYSICAL BASIS OF MEMORY

Information enters the brain as brief impulses transmitted over nerve cells. For long-term storage these impulses must be converted into changes in the structure of the nervous system. What these changes are and how they occur are still mysteries, but we have some ideas. It is thought that entering nerve impulses set up active short-term processes that decay quite rapidly. In turn, these short-term processes induce the formation of more permanent traces.

Several lines of evidence support this view. In one kind of experiment the activity of the brain is disorganized by an electrically induced seizure immediately after an animal has a learning experience. Imagine a rat that has just stepped from a platform onto a hot floor. If the activity of his brain is disrupted within five seconds after the experience, he will step off just as fast the next time. He will show no sign that he remembers the condition of the floor.

Other evidence comes from certain pathological conditions that have been observed in man. When the temporal lobes of the brain are destroyed by disease or removed by surgery for tumors, a person may lose his ability to store new information. He



After something has been learned, the amount of retention can be determined by taking a test. Actually, tests help to prevent forgetting, especially if the material is fairly well learned.

Hays, from Monkmeyer

retains his old memories: he still knows his name, knows how to talk, is able to perform customary tasks, and so on. His short-term memory may be unimpaired. He can still recall the same number of digits immediately after hearing them. But he may be completely unable to remember anything new for more than a few minutes. He may not remember a new name or phone number, or even that he was looking for something by the time he walks the length of a hospital corridor. New memories simply are not entered in a permanent form.

How is information stored in the nervous system? One widely favored possibility is that a physical change occurs at nerve junctions called *synapses*. A synapse is the place where one nerve cell meets another. It is where impulses are transmitted from one path in the nervous system to the next. If experience and practice can alter synapses, there will be changes in the path that impulses take through the nervous system. This, in turn, will change the individual's behavior.

A second possibility involves a fundamental change in the metabolism of particular nerve cells. For example, the change might be in the structure of molecules important in determining the structure and function of a cell.

If memory is stored in the form of altered molecules, some investigators have suggested that it might be transferable. They suggest that an animal's memory may be transferred by extracting these molecules from its brain and injecting them into another organism. To test this theory, rats, mice, or flatworms are trained to make a response. Then one or another of these kinds of molecules is extracted from the trained animals and injected into untrained animals. The recipient animals are then trained in the same task, and their learning compared with that of *control animals*, or ones that receive injections from untrained donors. Some investigators have reported positive results. But there have also been many negative or inconclusive results, so that a great deal of caution is necessary when interpreting the data.

Another interesting question is the location of memory in the nervous system. Are there special parts of the brain that are responsible for storing memories? Early investigators theorized that if they removed portions of a rat's brain, bit by bit, the rat would lose, one by one, the habits he had previously been taught. This did not prove to be the case. Instead the scientists found that whole large areas of the brain had to be removed before there was any appreciable effect on the animal's memory. It now appears that various parts of the brain are specialized for functions such as analyzing certain qualities of experience or organizing certain aspects of responding, rather than for storing specific memories.

MAKING MEMORY WORK

There is no magical formula available yet for making everyone a wizard of memory. Many of the gimmicks that one hears about have proven to be mostly wishful thinking. For example, learning in sleep has never been shown to be effective. Indeed, one of the most important requirements for learning is to pay attention. This also relates to the use of hypnosis, another potentially "magic" learning aid. Under hypnotic suggestion people do learn a little faster, but the advantage is of just the magnitude expected if a person concentrates harder for any reason.

There are many variables that may make a difference in how well you learn and remember something. We have already mentioned the importance of spacing practice. It is usually better to study or practice a particular thing a little at a time rather than all at once, at least insofar as its meaning and logic are not impaired. Even the way in which a flash-card deck of, say, French-English vocabulary equivalents is arranged for memorization can make a difference. If the same card is studied twice in a row, the second practice does almost no good. It is best to study one card for a while, then put it away while you study at least six or eight others.

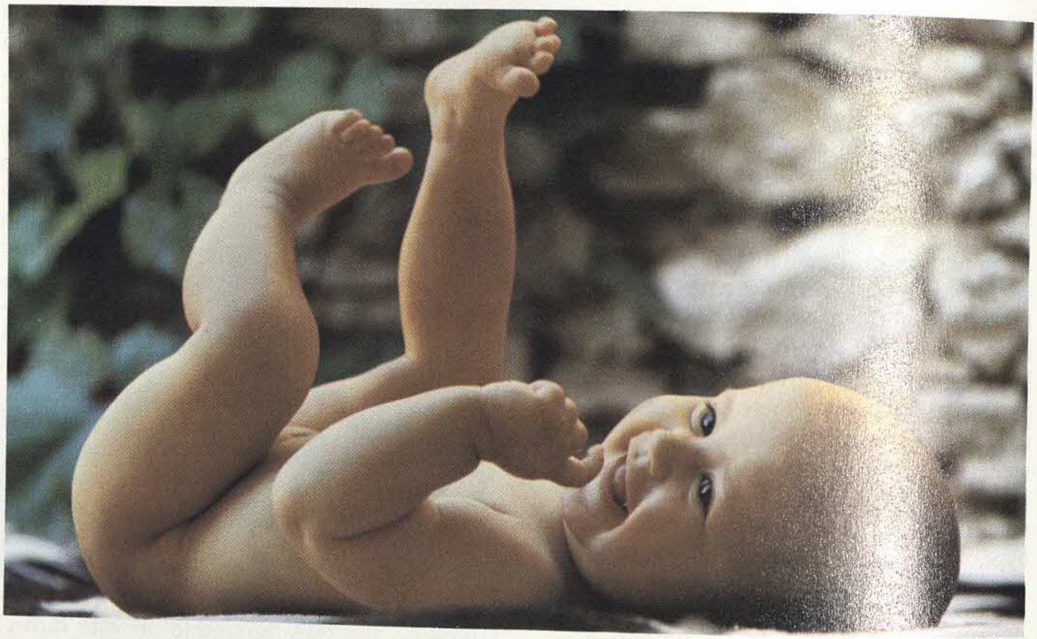
After something has been learned, the degree of retention may be greatly influenced by the manner in which practice was organized. If instead of learning just to master, the learner goes on to study more, his rate of forgetting is much less rapid. Tests are even more effective in preventing forgetting. In some cases less will be forgotten in a month with a properly arranged test than in a single day without one. Tests are probably most effective, as compared with just more studying, when the material is already fairly well learned.

Certain methods of organizing information as it is learned can make it easier to retain and retrieve. These "tricks" are sometimes called *mnemonic devices*. For example, medical students often try to remember a sequence of nerves by memorizing a poem in which the first letter of each word stands for the first initial of a nerve. Junior-high-school students use the same trick to remember the order of planets: "My very energetic mother jumped swiftly underneath Pluto." Another technique is to create a vivid visual image – one full of bizarre and unusual features – incorporating the thing or things to be remembered. To remember Mr. Appleby, imagine a large red apple with a B on it. Another method is to invent a code by which a complicated pattern can be reduced to a simple one. Or if you were trying to remember a large number of words without respect to their order, it would help to group similar words together – all things having to do with farms, for example.

These memory aids work by organizing the material to be learned and making it more meaningful. They thus take advantage of things the person already knows to help make new connections more varied, rich, and salient. Under what conditions these various memory aids work and do not work has not yet been established.

Does memorizing make a person a better memorizer? The answer is complicated. By memorizing nonsense syllables, you will not become better at learning poetry, French, biology, or baseball averages. On the other hand, memorizing nonsense syllables will influence in two ways your future memory for nonsense syllables. The more nonsense syllables you learn, the faster you will learn them. But you will also begin forgetting them more rapidly.

The use of various memory aids, together with proper organization of practice time and other good study habits, will increase your ability to learn and retain information. But simply doing a lot of memorizing will not strengthen your memory. In general, practice makes you good only at exactly what you learned. But, if what you learn is applicable in detail in new situations, you will be better off.



HUMAN EMBRYOLOGY

by Charles C. Macklin

Human beings are mortal and their life span is comparatively brief, even under ideal conditions. Fortunately, like all other living things, human beings can reproduce their kind and thus assure survival of the species.

One-celled forms of life, such as amebas and diatoms, reproduce by fission: a cell divides into two, and each of these represents a new individual. Fission also occurs among certain multicellullar organisms. Some of these life forms reproduce vegetatively. A part of the original organism, removed from the main body, grows into another organism of the same type. Other plants and animals bring new representatives of their species into being by means of single cells called *spores*.

SEXUAL REPRODUCTION

In the higher forms of life and in many of the lower forms, too, sexual reproduction takes place. Two kinds of sex cells, or *gametes*, are involved in the process: the male gamete, or *sperm*, and the female gamete, which is called the *ovum*, or *egg*. Under normal conditions, only when an egg is fertilized by a sperm can a new individual arise.

The sex cells of humans represent only a part of the many thousands of millions of cells found in the human body. Each cell contains a core, or nucleus, in which there are a number of *chromosomes*. At certain phases of cell division, the chromosomes are elongated and intertwined. At other phases, they become shorter and thicker, forming distinct units. Chromosomes carry hereditary factors called *genes*. Human cells – except for mature sex cells – generally have forty-six chromosomes. Mature human sex cells, however, have only twenty-three chromosomes.

The sex cells of humans are produced in the *gonads*, or sex glands – the *ovaries* in the female and the *testes* in the male. A number of accessory sex organs also serve the reproductive process. These organs include the *penis* in the male and the *uterus,* or womb, in the female. Certain secondary sex characteristics also develop. Among these are hair growth on the face in males and breast development in females.

FEMALE SEX ORGANS

The *ovaries,* in which female sex cells—the *ova*—are produced, are almond-shaped structures, which lie in the pelvis. The ova develop from cube-shaped cells covering each of the two ovaries. Columns of these cubical cells penetrate deep within the ovary. Tiny cell groups then break off from the penetrating columns. These groups are called *primitive Graafian follicles.* Each consists of a comparatively large cell, surrounded by a single layer of smaller cells. The central cell is the primitive ovum, which may later develop into a mature ovum.

Within the ovary of a sexually mature female, one of the primitive Graafian follicles begins to mature from time to time. The cells surrounding the primitive ovum multiply until they form several layers. Finally the follicle ruptures and the ovum is discharged from it. This process is called *ovulation.* The ovum, still immature, makes its way from the ovary into a slender tube—the *Fallopian tube*—where it becomes mature. There are two Fallopian tubes, one leading from each ovary. It is while the ovum is in one of the Fallopian tubes that it may be fertilized by a sperm. The ovum finally makes its way into the broader end of the uterus, a hollow, pear-shaped organ. If the egg has been fertilized and if conditions are favorable, it will develop into an embryo in the uterus. If it has not been fertilized, it will degenerate and will be passed out in the menstrual flow.

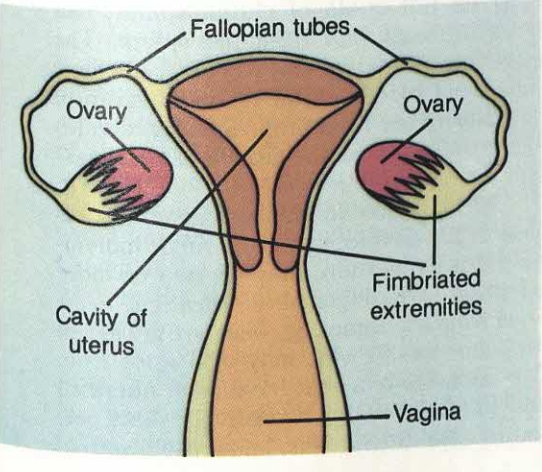
The small, narrow end of the uterus is called the *cervix.* The cervix opens into the tubular *vagina,* which receives the male organ in the act of copulation, or sexual union. In the case of virgins, the opening to the vagina is usually partly closed by a membrane called the *hymen.*

We noted that the breasts, or *mammary glands,* of women are secondary sex organs. They are made up of a mass of glandular tissue, which can secrete milk when properly stimulated. The milk is transported along ducts to the *nipple,* from which it is withdrawn by the suckling infant. The nipple is covered by dark skin. It is surrounded by a dark area called the *areola.*

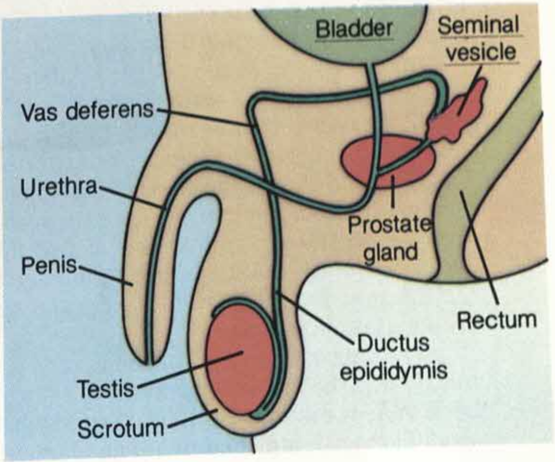
MALE SEX ORGANS

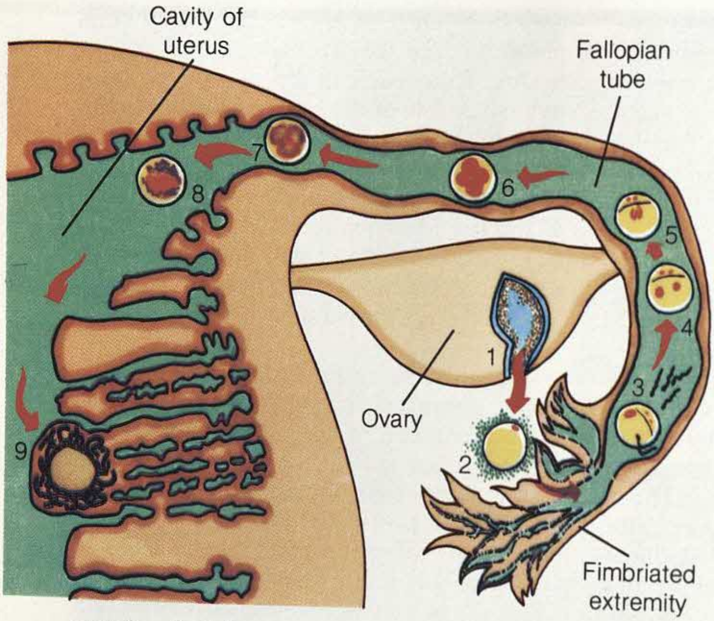
The two testes of the male are egg-shaped bodies, which are enclosed in a

The ova are produced all at once, but usually only one ovum matures at a time and is released from the surface of the ovary.



The testes of the male are counterparts of the ovaries of the female. Unlike ovaries, they produce sperm for many years.





1. Graafian follicle discharges egg. 2. It moves to the Fallopian tube. 3. A sperm enters the egg. 4. The egg continues moving along the tube. 5. The two cells fuse: this is fertilization. 6. The zygote begins to divide. 7. Morula stage. 8. Morula enters uterus. 9. Morula becomes implanted in uterus.

pouch called the *scrotum*. The scrotum is outside the body cavity, at the bottom of the abdomen. The sperm produced in the testes are transported to the female sex organs by way of the external male organ called the *penis*. The penis also serves to discharge urine.

After leaving the testis, the sperm travels along a slender twisted tube, over six meters in length—the *ductus*, or *vas, epididymis*. This elongated tube leads into the *ductus*, or *vas, deferens*. This is a muscular tube with a much larger caliber than that of the vas epididymis. The duct from the *seminal vesicle* empties into the vas deferens. Each of the two testes has the conducting system that we have just described.

In the course of the act of copulation, the seminal vesicles emit a secretion in which the sperm coming from the testes are suspended. These products are transported to the upper end of the *urethra*, the canal running through the penis. There they mix with the secretions from a gland called the *prostate gland* and from other glands of the urethra. The mixture of sperm and secretions is called *semen*.

The sperm have now become very active. Under the microscope they are seen to be in violent motion. Each has a somewhat spadelike head, attached to a long filament, the *flagellum*, which propels the sperm by means of lashing movements.

FERTILIZATION

After the semen has been deposited in the vagina as the result of copulation, sperm make their way up the uterus by their own movements and by contractions of the uterus. Then they enter the Fallopian tubes. If there is a mature egg in one of the Fallopian tubes at this time, a sperm may penetrate the egg. When this happens, the male and female *pronuclei* merge. This constitutes the act of *fertilization*. The cell is now known as a *zygote*. It now contains its full quota of chromosomes, half from the egg, half from the sperm. The materials from two lines of descent have thus been blended, and the mechanism of heredity is set in motion. The cell divides again and again, as the growth of the organism continues.

Fertilization in humans generally results in the development of a single individual. However, there may be two or more offspring at a single birth. *Identical twins* arise from the same egg. They are always of the same sex. Twins may also arise from two separate ova that have been liberated and fertilized within a relatively short period of time. Such twins, known as *fraternal* *twins*, may be of different sexes. Usually they do not resemble one another any more closely than ordinary brothers and sisters.

The same general principles apply to the formation of triplets, quadruplets, and quintuplets. Mixtures of single-egg and multiple-egg offspring may occur.

EARLY STAGES OF DEVELOPMENT

During the earlier stages, the developing egg – the product of fertilization – bears no resemblance at all to the baby that is to be. It is a mere blob of microscopic cells, each with a nucleus that is capable of dividing and dividing again until ultimate growth is reached. The baby is the result of hereditary properties of the mother's and father's sex cells. The only valid prenatal influences are those of the environment in which the unborn child develops. For example, it will be influenced by certain diseases that may attack the mother. It will also be badly affected by excessive amounts of alcohol the mother might drink.

At first the embryo consists of a little ball of cells, called a *morula*. This soon develops an outer and inner layer. The interior of the ball fills with fluid. Numerous fingerlike "sprouts" form on the exterior, which begins to look quite fuzzy. The outer covering of the tiny ball is called the *chorion*. The fingerlike sprouts that form on it are known as *villi*. Meanwhile the embryo has arrived in the uterus.

THE UTERUS AS HOME FOR THE EMBRYO

In the meantime the mucous membrane of the uterus has undergone certain vital changes in preparation for the possible arrival of a fertilized egg. Under the action of the hormone called *progesterone*, the mucous membrane has come to form a soft tissue, which is abundantly supplied with blood vessels. This newly formed tissue is known as the *decidua*. The embryo embeds itself in the decidua in the process of *implantation*.

The ovum makes its way to the uterus from the Fallopian tube whether or not it has been fertilized. If fertilization has not taken place, the ovum degenerates. The inner lining of the uterus, which had been prepared for the embryo, is shed, together with a certain amount of blood, in the process of *menstruation*. The *menstrual cycle* lasts about twenty-eight days.

Ovulation – that is, the discharge of an ovum from a mature Graafian follicle – occurs about midway between two menstrual periods. The menstrual cycle is repeated as long as a female is capable of bearing young, except during pregnancy, and also for a certain length of time after pregnancy.

Suppose now that the embryo has become embedded in the mucous membrane of the uterus. Its inner cells come to form the walls of two sacs, or baglike structures, called the *amnion* and the *yolk sac*. A group of cells known as the *embryonic shield* develops at the place where the amnion comes in contact with the yolk sac. The body of the embryo will be formed from this shield. As time goes on the cavity of the amnion becomes larger and larger, while the yolk sac shrinks and ultimately disappears. At last the amnion completely surrounds the embryo. The amnion has come to be filled with liquid.

When the embryo first becomes implanted in the uterus, the villi on the embryo's outer surface are surrounded by the lining of the uterus. The area where the villi project into the membranes of the uterus is called the *placenta*. This grows until it covers almost a third of the uterine lining.

The fetus develops in the *amniotic cavity*. It is connected to the placenta by means of the *umbilical cord*. Two umbilical arteries passing through the cord carry blood from the fetus to the placenta. An umbilical vein returns blood from the placenta to the fetus.

The circulation of the mother and of the fetus come into close contact in the placenta. Yet the blood in the mother's circulation system does not mix with that in the vessels of the fetus. Oxygen and food elements contained in the capillaries of the mother pass to the capillaries of the fetus. Carbon dioxide and other wastes pass from the capillaries of the fetus to those of the mother.

EMBRYONIC LAYERS

In the meantime, the embryo has been developing steadily from the embryonic shield. Its cells soon form two layers—an outer one, called the *ectoderm,* and an inner one—the *endoderm.* A third layer, known as the *mesoderm,* soon develops between these two. All the structures of the body arise from these three layers.

The ectoderm gives rise to the skin, the nervous system, the lining of the nose, the outer parts of the sense organs, the lens of the eye, the pituitary body, the glands of the mouth, and the enamel of the teeth. From the mesoderm are developed the skeleton and the muscles, the heart and the blood and lymph vessels, the kidneys and ureters, the urinary bladder (but not including its lining), and the gonads and their ducts. The endoderm develops into the linings of the respiratory and alimentary tracts, various glands, and the secreting cells of the pancreas and liver.

For the first eight weeks or so of its growth, the unborn young is called the *embryo.* After this period of time it is known as the *fetus.*

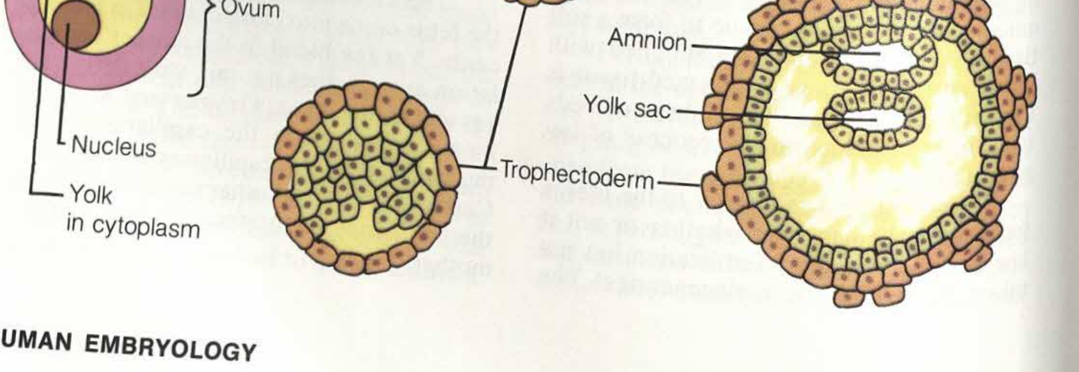
FORMATION OF THE BODY SYSTEMS

Let us now see how the various parts of the unborn human young develop. We shall take up the different systems of the body in turn, bearing in mind that they may be developing at much the same time.

The heart and blood vessels. In the early stages nutrition and wastes can pass quite effectively by diffusion between the cells of the embryo and the mucous membrane of the uterus. As growth advances, however, this system becomes inadequate. Specialized blood vessels are formed to transport nutrition and wastes. Together with the heart and blood, these vessels make up the extensive cardiovascular system. Without it, development could not proceed beyond the early stages.

We can trace the beginnings of the heart in the future neck region of the embryo. At first the structure that will develop into the heart is in the form of two tiny cavities lying side by side in the long axis of the embryo. Similar cavities develop in other places. They grow longer and send out branches, which join with other branches. In this way the larger arteries and veins

Early stages of embryonic development. Left to right: the egg has just been penetrated by sperm. After fertilization takes place, the egg divides again and again. A distinct outer layer—the trophectoderm—is formed, together with an inner cell mass. Two sacs have been formed at this stage—the amnion and the yolk sac.



develop. These channels soon unite with the primitive heart, whose cavities enlarge, elongate, fuse, twist, and later subdivide into four chambers – the left and right ventricles and the left and right auricles. Valves arise at the entrances to the ventricles. Later, the heart descends to the chest.

In the meantime groups of cells called *blood islands* have begun to form. The outer cells of these blood islands flatten and become the *capillaries* – the smallest blood vessels in the circulatory system. The inner cells develop into the different types of blood cells. The capillaries come to form a network, which is connected to the arteries and the veins. Fluid – the *plasma* of the blood – gathers around the blood cells.

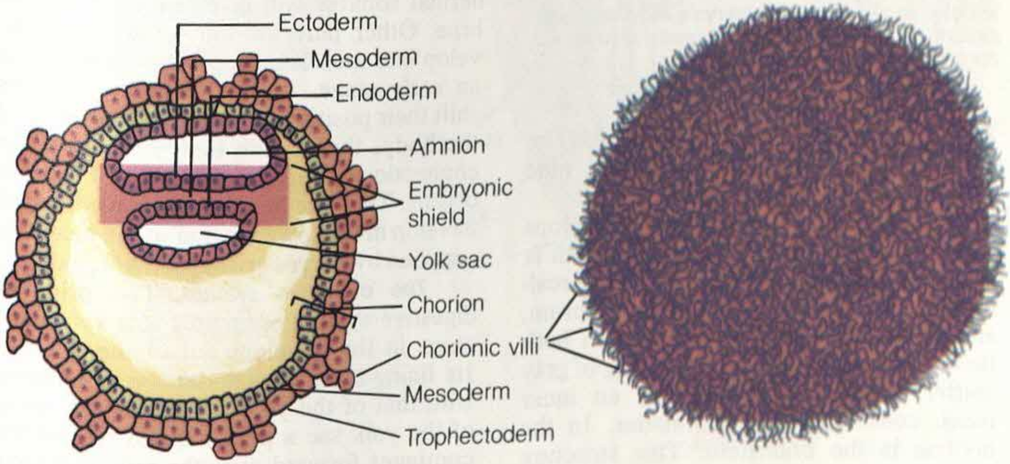
As the lungs are formed, they develop their own blood vessels, which are also connected to the heart. This lesser, or pulmonary, circulation, as it is called, does not operate fully until after birth, when the baby draws its first breath and the lungs begin to function.

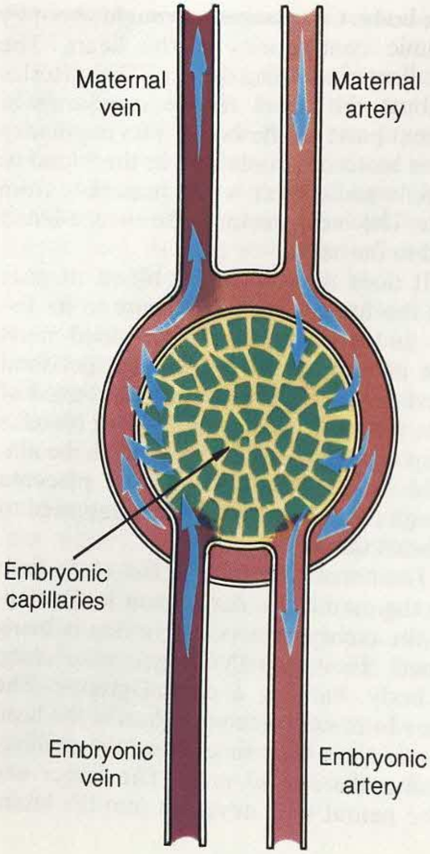
Long before this happens, blood begins to circulate through the arteries and veins and capillaries of the greater, or systemic, circulation, which passes through the rest of the body. Circulation is brought about by rhythmic contractions of the heart. The heart keeps pumping blood. The arteries distribute the blood to the capillaries in different parts of the body. The capillaries deliver materials contained in the blood to the cells and collect waste materials from them. The veins return the waste-laden blood to the heart.

It does not suffice for blood to pass from the human embryo's heart to its tissues and back again. Some blood must make its way to the placenta to get food materials and oxygen and to be relieved of waste products. We remarked that blood is transported to the placenta through the umbilical arteries and from the placenta through the umbilical vein. It is returned to the heart through the liver.

The nervous system. At the same time that the cardiovascular system is developing, the embryo's nervous system is being formed. First, parallel ridges arise along the body, flanking a central groove. The ridges form conspicuous bulges at the head end. In time they fuse along the midline, forming the *neural tube*. The larger end of the neural tube develops into the brain.

Early development, continued. Left: a group of cells – the embryonic shield – has developed at the place where the amnion comes in contact with the yolk sac. The body of the embryo will be formed from this shield. Right: external appearance of the fertilized egg. The outer covering is called the chorion. It is covered with sprouts called villi.





How materials are exchanged between the blood of the mother and that of the embryo. The arrows indicate the direction in which the blood flows. Note that the embryonic capillaries are bathed by maternal blood. Food and oxygen from the maternal arteries enter the embryonic capillaries and make their way to the embryonic arteries. Waste materials are discharged from the embryo's veins and, after passing through the capillaries, make their way to the maternal veins.

The rest develops into the spinal cord. The openings at the ends of the neural tube ultimately close.

The central nervous system develops from this primitive neural tube. Growth is most rapid of all in the brain. There are really two brains: a large brain, the cerebrum, and a small one – the cerebellum. In both there is ultimately an outer covering of gray matter, called the cortex, and an inner mass, consisting of white matter. In the midline is the brainstem. This structure connects the brain with the spinal cord.

The cavity of the neural tube continues to grow larger, though not at the same rate as the tissues that surround it. As the brain develops, the cavity within it forms spaces filled with fluid. In the spinal column, the cavity of the neural tube makes up the inconspicuous central canal.

In the course of the development of the neural tube, two lines of tissue appear between the tube and the overlying skin. They become segmented and form a paired series of *dorsal root ganglia* – the cell stations of the sensory nerves leading to and from the brain and spinal column.

The skeletal and muscular systems. Underneath the impressive mass of the central nervous system, a rod of cells – the *notochord* – has grown forward from the tail end of the embryo. It forms a central axis, around which the vertebral column develops. The notochord extends forward into the base of the skull. In time it disappears almost entirely. However, the central part of each disk, between the vertebrae, is retained.

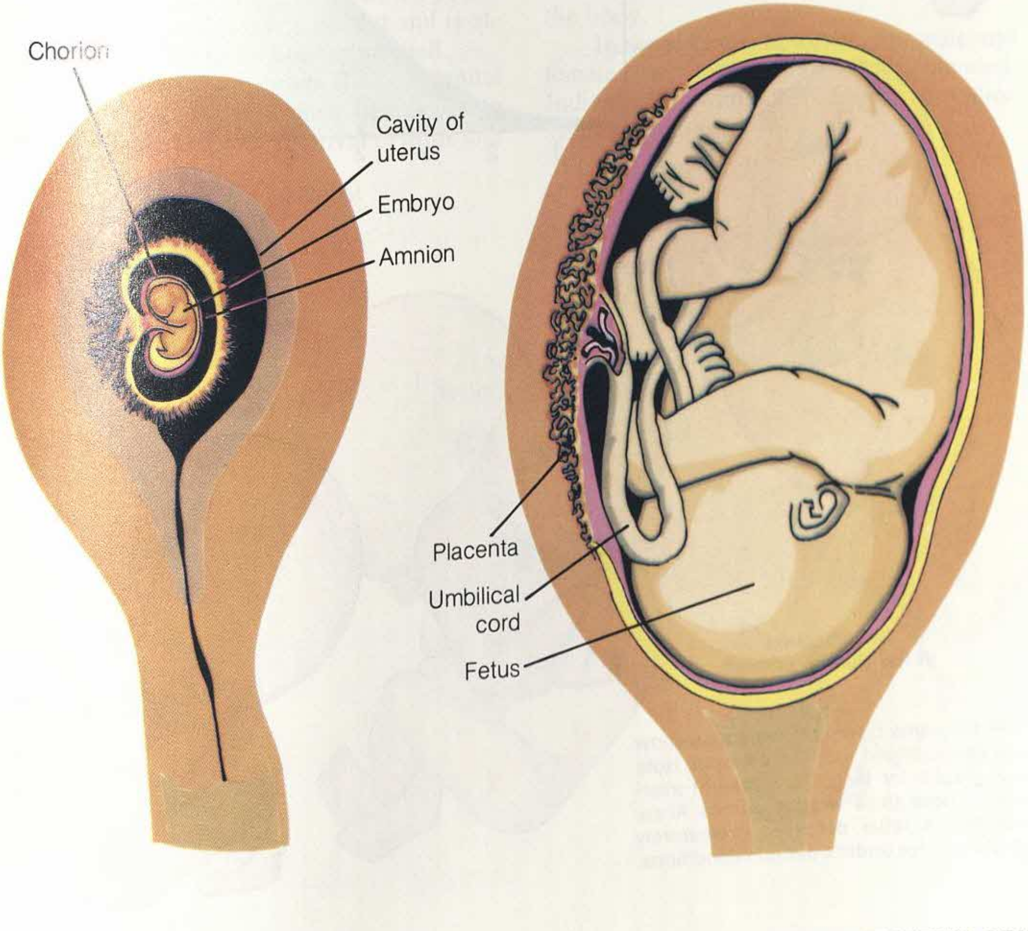
Hardly has the notochord made its appearance when strips of mesoderm form alongside it. These soon become a series of paired blocks. The first to appear are in the lower part of the head. They are then added in pairs farther down the notochord, until in the fourth week their number reaches forty. They are called *mesodermal somites* and are found in all vertebrates. Parts of mesodermal somites will give rise to the vertebrae. Other parts of the somites will develop into muscles, supplied with nerves at an early stage. Later, when the muscles shift their positions to more distant parts of the body, they retain their original nerve connections. This is also true of various organs. Thus the heart and stomach, which develop in the lower region of the head, are supplied by nerves arising in that region.

The digestive system. The primitive digestive system originates at a very early stage in the development of the embryo. Its lining layer of endoderm is continuous with that of the yolk sac. From the cavity of the yolk sac a pouch called the *foregut* continues forward over the primitive heart and under the head region. Behind, extending into the tail region is a similar pouch – the *hindgut*. An intermediary region, known as the *midgut* (really part of the yolk sac) connects the two guts.

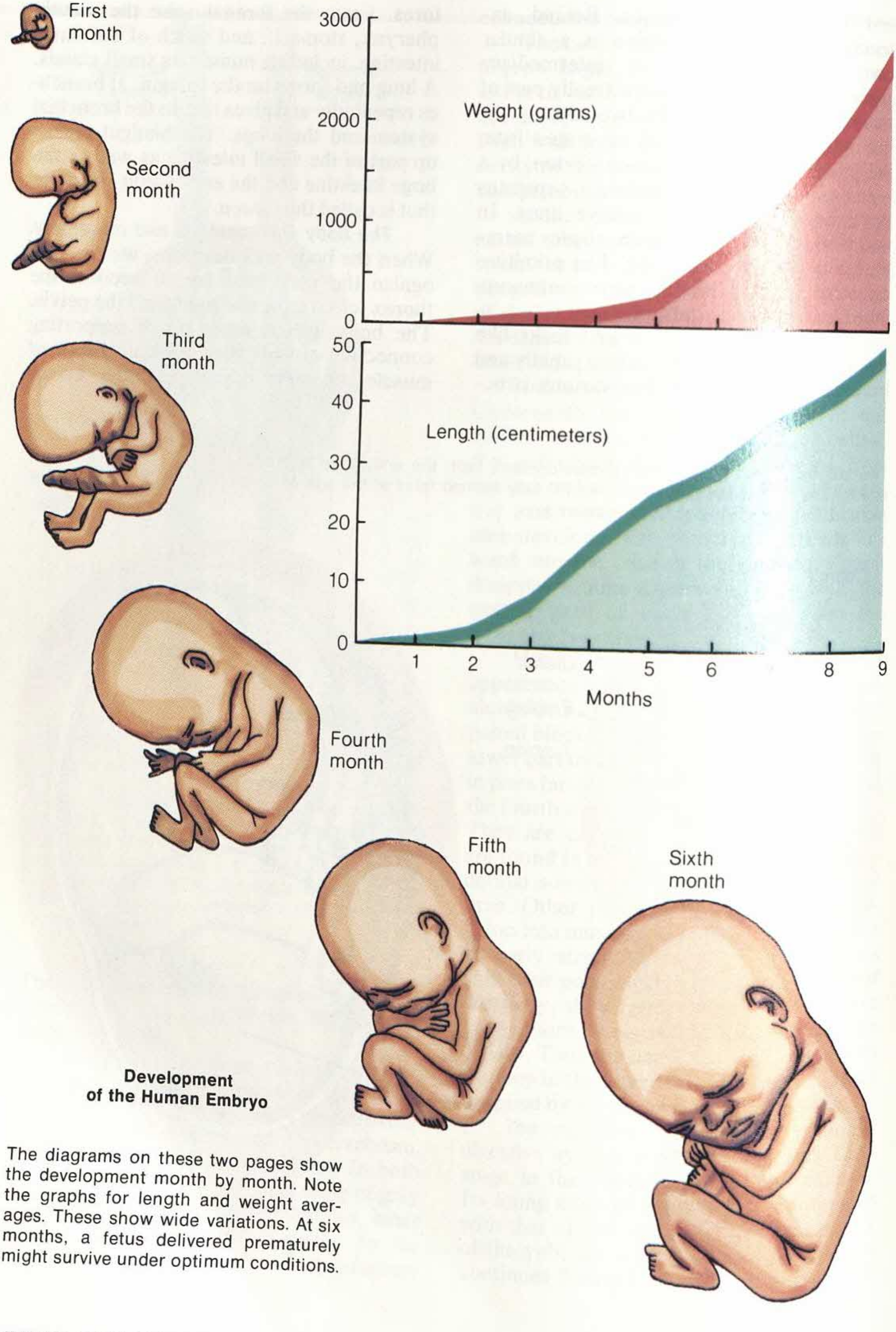
At first the foregut is separated from the primitive mouth, or *stomodaeum,* by a membrane. Another membrane separates the hindgut from the primitive anus. In normal development, both these membranes ultimately disappear. The primitive digestive system then forms a continuous tube from mouth to anus.

The foregut, which at first looks like the finger of a tiny glove, grows rapidly and becomes differentiated into various structures. From the foregut arise the mouth, pharynx, stomach, and much of the small intestine, including numerous small glands. A lung bud forms on the foregut. It branches repeatedly and gives rise to the bronchial system and the lungs. The hindgut makes up part of the small intestine as well as the large intestine and the embryonic structure that is called the *cloaca*.

The body wall, coelom, and mesentery. When the body wall develops, we can recognize the parts that are to become the thorax (chest), the abdomen, and the pelvis. The body wall is made up of supporting connective tissue, with special sheets of muscle to serve for movement. Tissue



Two stages in human embryonic development. Left: the embryo at age one month. The chorion is still visible. Right: fully formed fetus at the age of nine months. The fetus is in position for delivery.



Development of the Human Embryo

The diagrams on these two pages show the development month by month. Note the graphs for length and weight averages. These show wide variations. At six months, a fetus delivered prematurely might survive under optimum conditions.

called *mesenchyme* forms in parallel lines at right angles to the axis of the body. These parallel structures change into cartilage, and later mainly into bone. They are then recognizable as the ribs. The upper members of these elements are joined in front by two parallel bars of cartilage. These fuse to form the sternum, or breastbone.

As the body becomes walled in, the future chest and abdomen form a single hollow space called the *coelom*. It is separated lengthwise into two parts by a primitive membrane, called the *mesentery*. Soon a septum, or wall, which becomes the diaphragm, separates the chest from the abdomen. In front of the heart and intestine, the mesentery disappears. The rest of the mesentery in this part of the body undergoes great changes. The hind part of the mesentery lengthens as the intestine to which it is attached becomes longer. Part of the posterior (hind) mesentery lies against and is attached to the posterior abdominal wall.

The urogenital system. The urogenital system includes the organs having to do with the production or removal of urine and with reproduction. In the early stages of the human embryo, there is a primitive kidney, the *pronephros,* which gives way to a more advanced kind of kidney – the *mesonephros*. The mesonephros contributes important parts of the male reproductive system. Later the permanent kidney, the *metanephros,* is formed. This organ removes waste materials from the blood. In the unborn young these materials first pass through ducts, called *ureters,* into the cloaca. Later the front part of the cloaca becomes the bladder. This discharges urine from the urethra.

The sex glands, or gonads, are alike in the early male and female embryo. Soon however, they become differentiated and can be distinguished as the ovaries and the testes. The testes are at first contained within the body. Later they descend into the scrotum. Occasionally they fail to make their way to the scrotum, but remain within the body.

In some cases, however, the male and female characters are more or less blended. Individuals in whom this happens are called *hermaphrodites*.

The arms and legs. In the lower neck region of the embryo, paired limb buds appear. They will become the arms. In time the tips show five ridges, representing the future fingers. Cartilage is formed in the central axis of each arm. Later this cartilage is transformed into bone. Joints appear at the end regions of the bones. Muscles developing around these parts become attached to the bones and bring about helpful movements. Blood vessels and nerves develop together with these structures. Far back in the trunk, paired buds, representing the legs-to-be, appear. They develop in much the same way as the arms.

In the limbs and throughout the body and head parts, a system of lymphatic vessels forms in the embryo. This will represent a tributary system for the veins, collecting fluids from various areas.

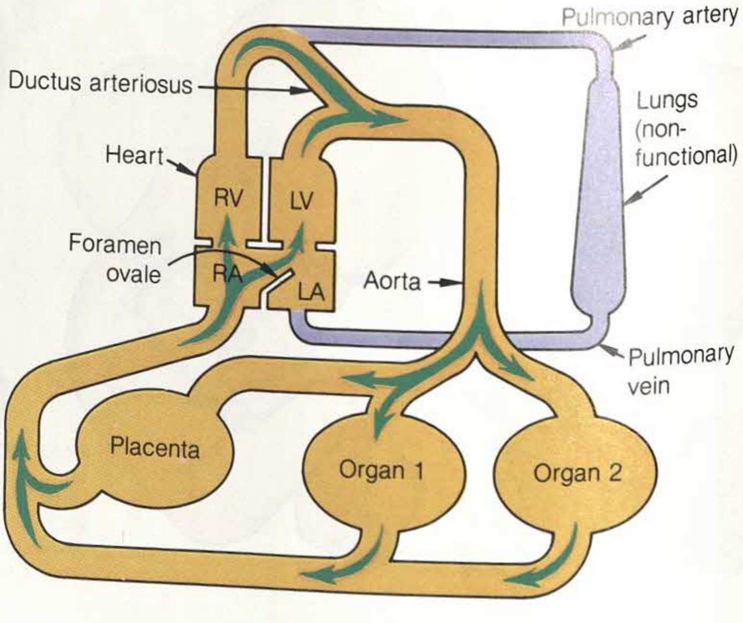
The head. Besides the skull and brain, the head includes the mouth, nose, eyes, ears, and tongue. The skull is formed at first of soft connective tissue or membrane. Much of this is transformed later into cartilage. The cartilage never occurs over the roof of the brain, but only on the floor and sides. Eventually it develops into many of the bones of the skull.

Early in the third month of pregnancy, though the skull is only about as large as the tip of one's finger, it already shows in a rudimentary condition the different bones that form it. However, even at birth, the brain is not completely enclosed by bone. In some areas, called *fontanelles*, it is covered only by membrane. The largest of these areas is on the top of the baby's head. The fontanelles are gradually closed up with bone.

In the early embryo the mouth and nose regions are merged in the stomodaeum. Shelves grow from its sides. Normally they meet after a time to form the palate, which shuts off the mouth from the nose. If the process should fail, we have the serious defect called *cleft palate.* This is often combined with the condition called *harelip*, in which the upper lip is divided.

The lower jaw is immovable and wide open in the early stages. It is first represented by an arch of cartilage. Later the mandible is formed by paired bones at the sides of the cartilage. The hyoid bone, under the tongue, and the larynx skeleton are also developed.

At birth there is still much cartilage in the skull as well as in other parts of the skeleton. Some of it persists throughout life



The circulation system before birth. Oxygenated blood from the placenta mixes with blood from various organs and flows to the right auricle. Some of the blood passes through the foramen ovale into the left half of the heart, and from there to the aorta. Some of it enters the right ventricle and passes through the ductus arteriosus on its way to the aorta. Practically no blood passes through the lungs at this time.

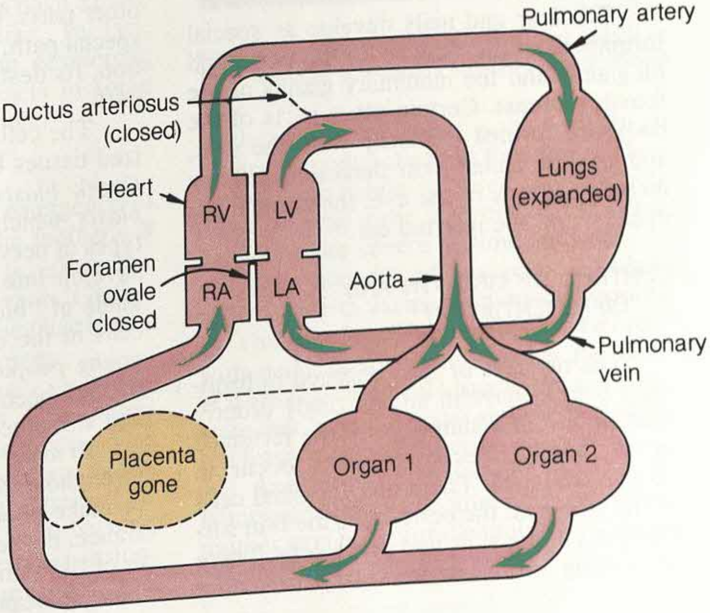
in places where its properties make it an ideal structural material. It is found in the joints, the larynx, the nose, the juncture of the ribs and the breastbone, and in various other parts of the body.

In the early stages the head is bent forward so that it almost meets the future chest, and the neck is practically nonexistent. In the course of time the neck develops and the head is raised somewhat. It is still bent forward, however, even up to the time of birth. The entire fetus is packed into the smallest space possible, curled up so that it is almost egg-shaped. This form is retained for some time after birth as the baby is held.

In their earliest form the human eyes occur as two dimples on either side of the brain. Each dimple changes into a spoon-like structure, which becomes the *optic cup*. The inner membrane of the cup develops into a specialized layer of cells called rods and cones and into neurons, or nerve cells, connected with them. The nerve cells establish connections with the optical centers in the brain by means of the optic nerve.

When the baby is born, therefore, it has a mechanism that can be stimulated by light and that can transmit the stimuli to the brain. The outer membrane of the optic cup forms a layer of densely pigmented cells, which keep out all light other than that coming in through the pupil. Generally the development of all these eye parts is almost perfect. Occasionally, however, defects occur, and these may be of a serious nature.

The ears develop quite differently. They are related to the *branchial arch* region. While the embryo is still very small, a minute pit develops above the first *branchial cleft*. The pit becomes deeper, and is closed off in time to form a hollow ball. It soon becomes irregular as it grows. It is transformed into a set of three arched tubes – the semicircular canals – and a small seashell-like structure, the cochlea. The end organ of hearing – the organ of Corti – develops in the interior of the cochlea. Meanwhile the middle and the external ear are being formed. The outer part of the external ear develops a supporting shell-like cartilage, which enables it to retain its shape. In the depths of the canal that leads from the opening of the external ear, a thin membrane – the eardrum – is formed. It closes up the canal. The eardrum vibrates when it is struck by sound waves. Three bones called ossicles arise in the middle



The circulation system after birth. Several vital changes take place. The placenta is gone. The foramen ovale and the ductus arteriosus have been closed off. Venous blood now passes into the right auricle, and from there into the right ventricle. From there it flows in the pulmonary artery to the lungs, where it is oxygenated. The oxygenated blood then passes through the left auricle and left ventricle and enters the aorta.

ear. They transfer to the inner ear the vibrations set up in the eardrum.

An arch-shaped structure develops on each jaw, and it divides into ten *tooth buds,* which will form the milk, or primary, teeth. Thus there are twenty buds in all. Each bud forms an enamel organ, which is a minute ball of cells, almost hollow and bent in above or below. Other cells develop within the ball and form dentine. The enamel organ and the dentine work together. They secrete fibers that become impregnated with hard deposits rich in calcium. The soft inner core of the teeth develops blood vessels and nerves. The milk teeth are not visible until they have erupted in the mouth. The first is generally cut some months after birth. These primary teeth are shed during childhood and are replaced by the thirty-two regular teeth.

The skin and its derivatives. The skin proper, in the embryo, is continuous with the amnion, which is cast off at birth. An outer layer of cells, the epidermis, develops. Underneath it there arises another layer, the dermis, which contains nerves, blood vessels, and sweat glands. In the embryo there is also a special layer of cells, called the *periderm,* on the outside of the epidermis. The periderm is shed at birth. Most of it is washed off with the baby's first thorough bath.

The hair and nails develop as special formations of the skin, as do the sweat and oil glands and the mammary glands of the female's breast. Certain other parts of the body are formed primarily from the skin, and can be called skin derivatives. They include the lens of the eye, the cornea, the eyelids, and the internal ear.

CONTROL OF GROWTH AND DIFFERENTIATION

The myriads of cells engaged in forming a baby behave in an amazingly orderly manner. From a simple cell—the fertilized ovum—highly specialized cells occur in proper sequence. There are the gland cells of the stomach, the bone cells, the thin surface cells of the skin, and nerve cells. There is nothing more extraordinary in nature than this systematic development.

Why do two buds for the future arms and legs make their appearance at the right time and place, with their various simple elements properly arranged? Why do they grow so perfectly in every part—elbow, hip, knee, and ankle? How do the various muscles develop? How do they attach themselves to the right regions of the right bones? How do the muscles acquire nerves to move them and to register their state in the central nervous system? We could ask thousands of questions such as these.

The why and wherefore of the embryo's development is still largely a mystery. However, the science of heredity gives some help in understanding the processes involved. We assume, on the basis of our knowledge of heredity, that the fertilized ovum is packed with tendencies derived from all past generations and that development is simply the working out of these tendencies. We assume also that hereditary forces continue to act after birth throughout the life of the individual.

In the early stages of development there is a rapid sorting out of the different kinds of cells. Quickly, for example, the cells that are destined to make up the chorion are mustered out. From them are separated the cells that will form the villi and other parts. Once a cell is started on some special path, it tends to go on in that direction. Its destiny is established for the most part.

The cells that will give rise to specialized tissues bear the suffix *blast* (from the Greek *blastos:* "bud"). There are *neuroblasts,* which will give rise to the different types of nerve cells; *hemoblasts,* which will develop into blood cells; and many other kinds of "blasts." We might compare the cells in the early stages of the embryo to young people of a community, some destined to become engineers, others chemists, and still others doctors or lawyers.

In many tissues differentiation goes on throughout the life of the individual in order to make good the losses of cells. For instance, the cells making up the surface layer of the skin are worn off in daily use and must constantly be replaced. The same is true of cells in other parts of the body, such as the intestinal tract and the blood. This means that such areas must be provided with nests of blast cells, capable of regenerating this or that tissue. In the deepest layers of the epidermis there are the *chorioblasts*, or *Malpighian cells*, that can give rise to the cells making up the surface of the skin. In the bone marrow there is a great mass of hemoblast cells that can differentiate into still more specialized types of blast cells. The latter will give rise to the red blood cells and the different kinds of white blood cells.

In the case of some tissues, such as those of the nervous system, there are no reserve blast cells: once a cell is destroyed, it cannot be replaced. The brain, for example, must get along throughout life with the cell quota it has at birth or shortly thereafter. That is why polio is so serious. The cells that are destroyed because of its ravages cannot be replaced. Other groups of cells may be able to take over their functions, but unless this can be done, the loss is irreparable.

In the orderly development of the different parts of the body, often distant from one another, the hormones, which serve as chemical messengers, play a very important part. So does the nervous system. Doubtless, too, muscular movements have a more general effect than we realize. In fact, everything taking place in the developing embryo or fetus probably reacts in some way with the organism as a whole.

BIRTH

What we call *birth*—the emergence of the fetus from the body of the mother—is obviously not a beginning. It is, rather, the climax of a long sequence of events. Generally it occurs after the pregnancy has lasted from nine to nine and a half months.

The mother's body has made its preparations for the coming event. The uterus has developed strong muscle fibers. The fetus will be expelled from the uterus as the result of strong muscular contractions. The outlets of uterus and vagina have become softened and capable of great expansion.

As the time of birth approaches, the mother-to-be has *labor pains*, which are caused by contractions of the uterus. These contractions begin to force the fetus out. They become more vigorous and the pains become more severe as time goes on.

Elizabeth Wilcox

Newborns are carefully checked and identified. Their footprint is recorded on their birth certificate.

The intensity of any pain associated with childbirth varies from mother to mother. The severity of labor pains can be linked with many factors, among them the mother's previous medical history, her emotional state, her physical state, and the position of the fetus within the uterus.

Anesthesia is sometimes used to dull labor pains. Many doctors and prospective mother prefer "natural childbirth." Natural childbirth, or childbirth without anesthesia,

J. Baker/FPG

The late Dr. Virginia Apgar, shown here with a newborn, devised a scale—known as the Apgar scale—to measure the condition of a newborn. The baby's skin appearance, heart rate, respiratory rate, degree of vocalization, and muscular function are studied and measured. The use of this method of studying the newborn helps point out possible medical problems in the baby.

requires that the mother physically train for the birth of her young. Toning of important muscles, rhythmic breathing, and mental preparedness are important aspects.

In the last stages of labor, the mother aids in forcing out the fetus by voluntarily contracting the abdominal muscles. The amnion, the closed liquid-filled sac surrounding the embryo, generally ruptures before birth.

Usually the baby comes from the mother's body head first. Sometimes it emerges feet first. This is called *breech presentation.* It may be necessary to take the baby out by cutting through both the abdominal wall and the uterus. This is known as a *Caesarian section* or operation.

When the baby is born, it is still attached to the placenta by means of the *umbilical cord.* It draws nourishment and oxygen from the placenta and expels its wastes into it. The obstetrician ties up the cord close to the baby's body with tape. Then he cuts the cord on the mother's side of the tape. About twenty minutes after the cord has been cut, the *afterbirth,* made up of the placenta and embryonic membranes, is passed from the mother's body.

When the placental circulation is cut off by the tying of the cord, there is an increase of the waste-product carbon dioxide in the blood. This stimulates a center in the medulla oblongata, a part of the brain, and the baby usually begins to breathe as a result. If respiration does not begin, the attending physician must give aid. He may stimulate the skin by slapping the buttocks or in other ways. He may administer artificial respiration or even introduce oxygen into the air tract by means of a tube.

THE NEWBORN

When a baby is born, it has the same bodily parts as the adult, but they are smaller and differently proportioned. The head is relatively large, the legs relatively small. The nose is tiny, but it serves well.

A newborn baby is covered with blood and with a slippery, waxy substance called *vernix caseosa.* This substance keeps the fetus from absorbing the liquid in which it is immersed. Of course it no longer serves, once the infant has been born, and it is removed when the newborn is bathed.

THE MOTHER AFTER BIRTH

After the afterbirth has been ejected from the uterus, the so-called *puerperal period* begins. It is during this period, which lasts from about six to ten weeks, that the uterus and the other structures involved in birth are restored to a normal condition. The uterus shrinks to almost its original size as the now useless tissue is absorbed. While this is taking place, there is discharge, consisting mostly of blood and debris, from the vagina. Gradually the discharge slackens and finally it ceases entirely. The puerperal period is over.

HUMAN HEREDITY

by Theodosius Dobzhansky

An apparently unimportant event took place some three thousand years ago on the slopes of the Sierra Nevada Mountains in California. A tiny seed of a tree called the giant sequoia, *Sequoia gigantea,* fell to the ground and found conditions favorable for growth. As years and centuries passed, the tree that developed from the small seed grew larger and larger. Today it is more than 60 meters high and more than six meters in diameter.

A human lifetime is a mere episode compared to the lifetime of a sequoia tree. Yet man and the sequoia have more in common than we might think. The seed of the sequoia was a product of fertilization. The human body, too, begins its existence with the act of fertilization, when a microscopic male cell unites with a barely visible female egg cell. In the course of time, as we have seen, the seed of the sequoia grows to be a huge tree. The fertilized human egg develops in the mother's uterus into an embryo. The embryo becomes a fetus, and about nine months after fertilization, a baby is born. In due course the baby becomes an adult, increasing its body weight about twentyfold.

RAW MATERIALS

In order for a seed or a fertilized egg to become a sequoia tree or a man, much material has to be taken from the outside world and incorporated in the living body. In the case of sequoia, this material consists of water and mineral salts, taken up by the roots from the soil, and carbon dioxide, coming in through the leaves from the air. The materials from which the human body is constructed are to be found, of course, in the foods that we eat—foods derived from the fields, gardens, and meadows and even from the depths of the sea.

Before such foods can become a part of a living body, they must undergo a complete chemical change. Moreover—and this point is vitally important—each organism builds itself up from these transformed substances in a particular way. As a result, the mature product of the building process resembles, in composition as well as in structure, the bodies of the parents and other ancestors of the organism.

HEREDITY AND THE ENVIRONMENT

The process of transformation of food materials by a living body into a likeness of itself and of its ancestors is called *heredity.* An organism may reproduce rapidly (as bacteria often do) or slowly (as in the case of human beings and the higher animals and plants). In either case, the urge to multiply according to a definite hereditary pattern exercises an unrelenting pressure upon the environment in which the organism lives. This pressure of heredity reveals itself in the gnarled and twisted trees growing out of

Humans and sequoias have more in common than you might think. The woman and the sequoia at which she is looking each began as a tiny fertilized egg and grew into adulthood in accordance with a definite hereditary pattern.

Union Pacific Railroad

small fissures in apparently solid rock on lofty mountain tops, in the riot of vegetation in a tropical jungle, in the teeming life in a drop of water from a stagnant swamp, as seen under the microscope. Various factors, however, tend to oppose the pressure of heredity. Only certain substances can be used by organisms as food. Others are useless or even poisonous. Only certain localities, offering favorable conditions, can serve as dwelling places. Even when the environment is favorable, multiplication is checked by the exhaustion of the food supply, space limitation, and competition with natural enemies, parasites, and the agents of disease. Living beings are continually exposed to countless dangers that make survival a lucky accident and premature death the rule.

The agelong conflict between the pressure of heredity and the deterring factors present in the environment has resulted in the grand process of organic evolution. Instead of a single kind of organism, instead of a single heredity able to use only some few substances as food to be transformed into living bodies, we find in the world about us an immense diversity of organisms and heredities.

In the following pages we shall examine the hereditary process particularly as it applies to human beings. We shall also consider some of the more important consequences of this vital process.

FERTILIZATION

It is remarkable that the heredity that is able to organize inert materials into the living bodies of human beings is transmitted from parents to offspring through exceedingly minute quantities of living substance. Only some parts of the female sex cell – the egg – and the male sex cell – the spermatozoon – are directly concerned in the transmission of heredity. Examined under a microscope, an egg cell consists mainly of cytoplasm, in which are stored certain food materials to be used by the developing embryo. A little blob of a slightly more translucent material – the nucleus – floats in the cytoplasm. The spermatozoon, or male cell, which is to fertilize the egg cell consists of a head, which contains a nucleus, and a contractile tail – one that makes the spermatozoon capable of movement.

Rapid strokes of the tail propel the spermatozoon head forward and thus enable it to reach the egg cell. The spermatozoon then enters the egg, and the nuclei of both cells fuse together. This nuclear fusion is the act of fertilization proper. A new individual has now arisen. The fertilized egg and its nucleus divide into two cells, each with a nucleus. The two cells divide into four; the four, into eight. Eventually, the thousands of millions of cells and nuclei that compose the human body come into being.

CHROMOSOMES

When strongly magnified under a microscope, the cell nucleus reveals some interesting structures. A certain number of minute bodies, called *chromosomes*, can be seen inside the nucleus, particularly when the nucleus is in process of division. Most human cells contain forty-six chromosomes – twenty-three pairs. The sex cells, however, have only half that number – that is, twenty-three. When fertilization takes place, the twenty-three maternal chromosomes contained in the egg cell, plus the twenty-three paternal ones brought by the spermatozoon, combine and form the normal complement of forty-six chromosomes in the fertilized egg.

These chromosomes are not all alike. Some of them are larger than others. Some are rod-shaped, other hook-shaped, still others V-shaped. After examining many nuclei and chromosomes, one learns to recognize a chromosome by its shape, just as one recognizes the letters of the alphabet or the faces of one's acquaintances. The twenty-three maternal chromosomes are all different. The same is true of the twenty-three paternal chromosomes. But, with a single exception, which we shall discuss later, every maternal chromosome is matched by a similarly shaped one in the paternal set.

In the formation of most of the body cells, a cell division called *mitosis* takes place. In this process a cell gives rise to two cells, identical with the original one. A different types of division, called *meiosis,* takes place in the production of sex cells in the sex glands—the ovaries, in the female; the testes, in the male. First, the matching maternal and paternal chromosomes in a forty-six-chromosome cell of the sex gland are attracted to each other. They approach in the nucleus and become intimately paired. Then they unravel, but still lie side by side, so that the nucleus now shows twenty-three chromosome pairs. Some of these pairs have exchanged sections—a phenomenon called *crossing over.*

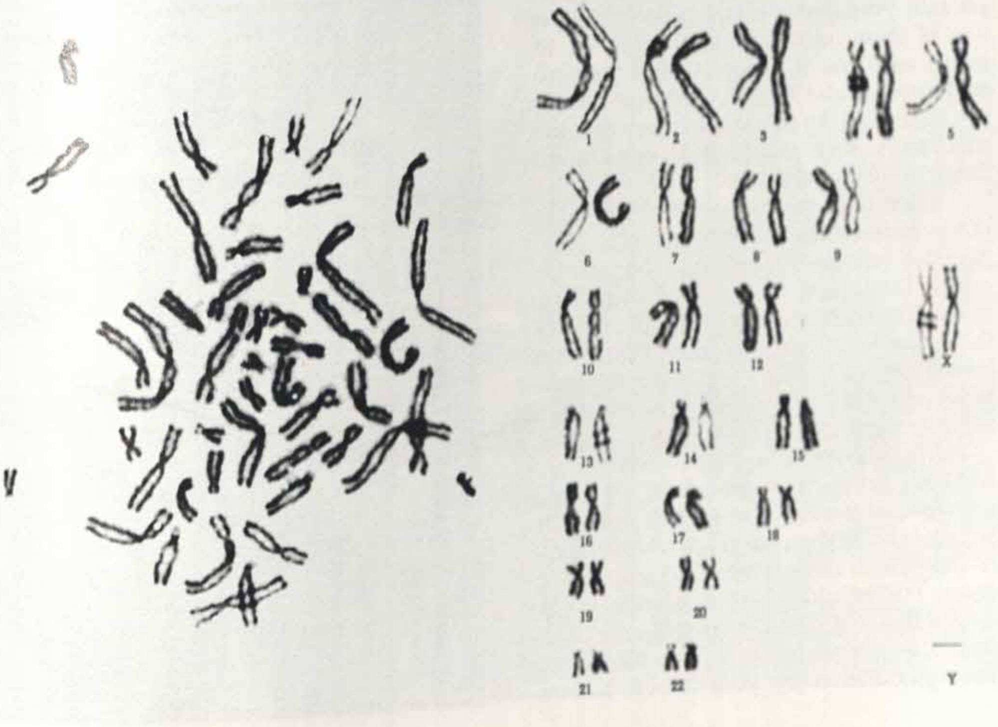
Each chromosome splits lengthwise, so that instead of twenty-three pairs, we have twenty-three *tetrads.* A pair is made up of two units; a tetrad, of four units. No further division of the chromosomes takes place. Next, the cell divides, forming two new cells, and then these two also divide. The original cell, therefore, has given rise to four new cells, each having twenty-three chromosomes—one from each of the twenty-three tetrads that were formed when the matched chromosomes divided.

In all his body cells except his sex cells, your father has forty-six chromosomes. He inherited twenty-three from his father and twenty-three from his mother. Your mother's cells also have for ty-six chromosomes—twenty-three of them from her father and twenty-three from her mother. How many chromosomes have you inherited from each of your grandparents? Have you and your brothers and sisters inherited the same chromosomes?

Let us indicate the chromosomes that your father derived from his father (your paternal grandfather) by letters with primes (A′, B′, C′, and so on), and the chromosomes he derived from his mother by letters with double primes (A″, B″, C″, and so on). Your father's chromosomes would be represented by this combination:

Chromosomes of a normal human female. Left: chromosomes as they actually appear in a cell. Right: chromosomes as they are paired and placed on a gene map. Chromosomes carry genes, the hereditary material.

B. Gefroy



A′B′C′D′E′F′G′H′I′J′K′L′M′N′
O′P′Q′R′S′T′U′V′Y*

A″B″C″D″E″F″G″H″I″J″K″L″M″N″
O″P″Q″R″S″T″U″V″X*

Only one member of each matching pair – A′A″, B′B″, C′C″, and so on – would get into the sex cells of your father; the distribution would be at random. For the sake of simplicity let us consider only three types of chromosomes – A, B, and C. In the sex cells formed by meiosis, there would be eight possible combinations of A, B, and C chromosomes, as follows:

A′B′C′
A″B″C″
A′B″C″
A″B′C″
A″B′C′
A′B′C″
A″B″C′
A′B″C′

In other words, the three grandpaternal chromosomes, A′, B′, and C′, may all get into your father's sex cells, or one or two of them may get into these cells, together with one or two grandmaternal chromosomes, or else they may not get into the sex cells at all. In the case of three chromosome pairs, there would be 2^3, or eight, different combinations.

Since man has, not three, but twenty-three chromosome pairs, the paternal grandparental chromosomes can be distributed in the sex cells of your father in 2^{23}, or 8,388,608 different ways. The probability, then, that you have inherited a full set of chromosomes (twenty-three in all) from your paternal grandfather is exceedingly slight – only 1 in 8,388,608.

Actually your chances of inheriting a complete set of chromosomes intact from a grandparent would be even less than that. We saw that in the process of meiosis some of the paired chromosomes exchange sections. The resulting chromosomes are no longer identical with the original ones. Suppose that chromosome A′, received from your grandfather by your father, had exchanged sections in this way in the formation of your father's sex cells. Even if chromosome A′ were to get into one of these cells, it would no longer be the same as the A′ chromosome in your grandfather's body cells.

Your brothers and sisters are no more likely to obtain exact replicas of all your grandfather's chromosomes than you are. Hence one may safely assert that brothers and sisters always have different hereditary endowments, unless they happen to be identical twins.

Below: these two young girls are identical twins. Such twins come from a single fertilized egg that splits in two in the early stages of its embryonic development. Identical twins differ from fraternal twins in that they have the exact same set of genes. Even so, environmental variations may be expected to produce differences.

Von Bucher/PR

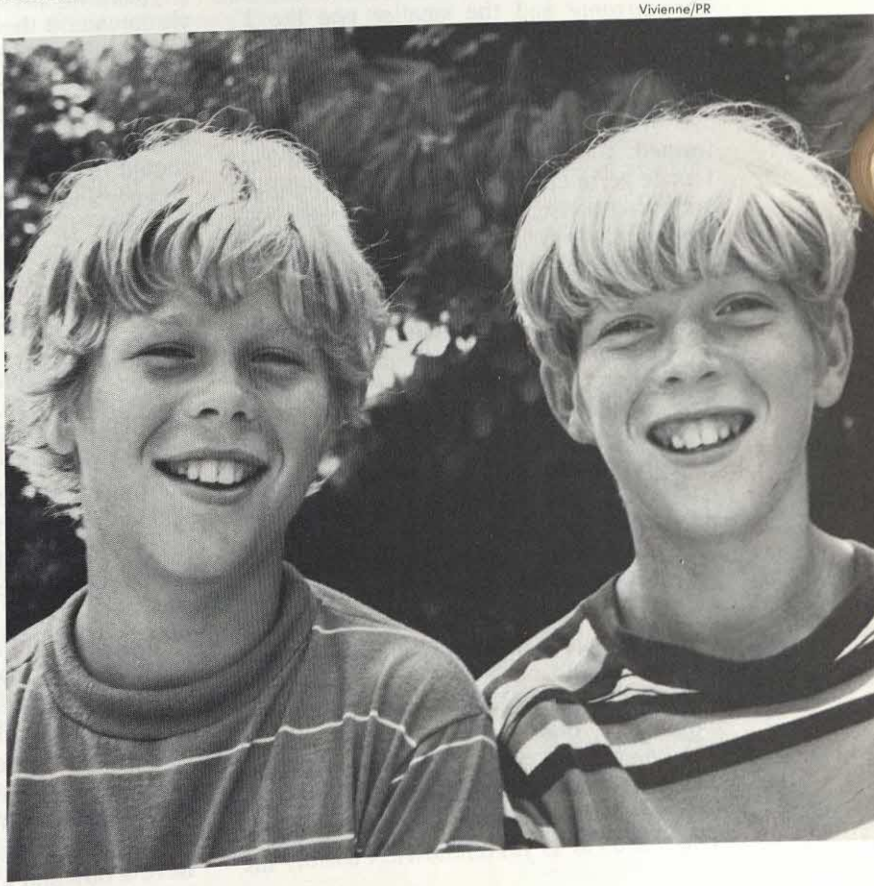
It is important to note how identical twins differ from so-called fraternal twins. Fraternal twins arise when two egg cells are simultaneoulsy fertilized by two different spermatozoa. The probability that the simultaneously fertilized eggs have similar combinations of chromosomes is no greater than it is for any two eggs produced by the same mother at different fertilizations. Consequently, the hereditary endowments of fraternal twins are on the average no more similar than the endowments of brothers and sisters not born at the same time.

Identical twins (or multiples) arise when a single fertilized egg gives two or more embryos, which developed into two or more babies. Since the process of cell division called mitosis involves an accurate splitting of each chromosome and an exact distribution of the halves to the daughter cells, identical twins possess identical chromosome complements and, therefore, have the same heredities.

Apart from identical twins, the possibility that any two human individuals, now living, or having lived in the past, or yet to live in the future, may have identical heredities is remote indeed. It is exceedingly small even in the case of brothers and sisters, with the same maternal and paternal grandparents. It is even smaller for unrelated individuals. Even in the case of identical twins, variations in the conditions of the environment may be expected to produce differences.

SEX DETERMINATION

What causes some babies to be girls and others boys? In other words, what determines the sex of an individual? This problem has stirred the curiosity of mankind since the earliest days. It has given rise to a great number of unfounded guesses



Vivienne/PR

Right: fraternal twins. Fraternal twins come from two separate eggs fertilized by two separate sperm. These twins have different gene sets and are no more alike than nontwin brothers and sisters.

and unjustified speculations. Only since the mechanism of chromosome distribution has become clear have scientists been able to offer a valid solution of the intriguing problem of sex determination.

When we made the statement that human body cells contain twenty-three matching pairs of chromosomes, we should have added that, strictly speaking, this is so only for the cells of a female body. In the case of a male body, there are twenty-two matching chromosome pairs, corresponding to those in female cells, plus a pair of chromosomes consisting of unequal members. One of the partners of this twenty-third pair is clearly larger than its mate. The larger partner resembles either member of the twenty-third, or X, pair of the female chromosomes. The smaller partner is not represented in the female chromosome complement at all. It is found in male cells only. Let us call the larger partner the *X chromosome* and the smaller one the *Y chromosome*. The female cells, then, contain two X chromosomes; the male cells, one X and one Y chromosome.

When female sex cells are to be formed, the two X chromosomes of the female germ cell come together. They then split lengthwise, forming four X chromosomes. Cell division subsequently yields four nuclei, each containing an X chromosome. In the formation of male sex cells, the single X chromosome pairs with its smaller partner, the Y chromosome. Each of these chromosomes splits lengthwise. The cell then contains two X chromosomes and two Y chromosomes. When this cell gives rise to four new cells – the sex cells – half will contan X chromosomes, the other half Y chromosomes.

If these two kinds of spermatozoa are equally efficient in reaching and fertilizing the egg cells, we should expect two kinds of fertilized eggs to be equally numerous. Half of them would have two X chromosomes (XX) and would develop into girls. Half would carry one X and one Y chromosome (XY) and would give rise to boys.

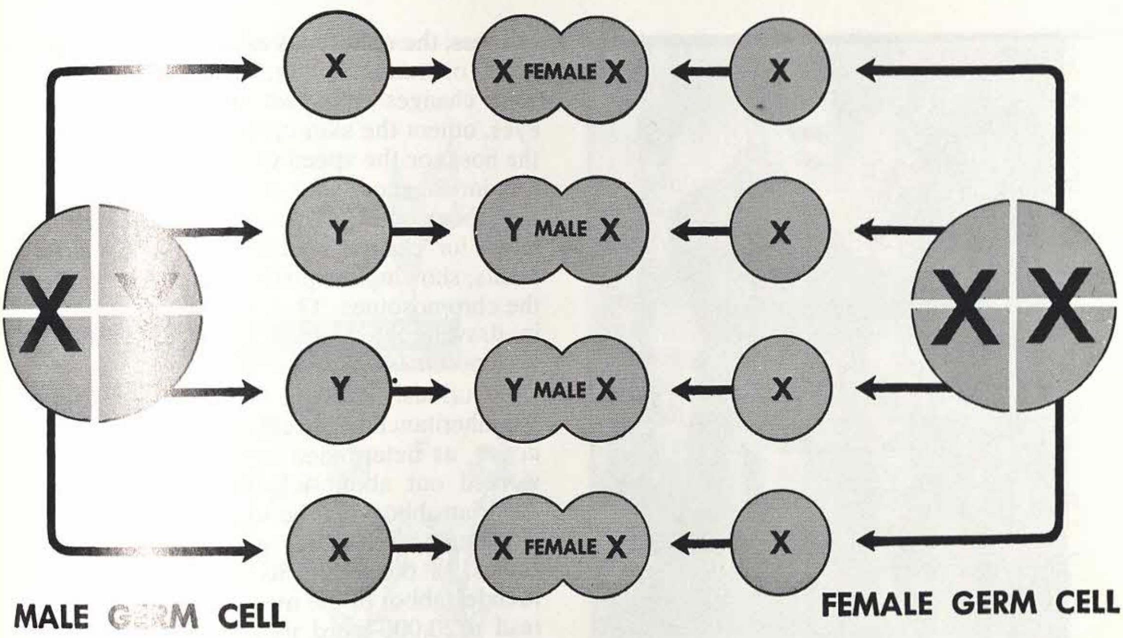
As a matter of fact, male births are slightly more frequent than female births. The reason is as yet unknown. Possibly the spermatozoa with a Y chromosome are a bit more efficient swimmers, or penetrate the egg cell more readily. Perhaps some of the XX fertilized eggs die off at early stages of their development. The acid-base balance of the female reproductive tract at the time of sexual intercourse also helps determine which type of sperm will be the most likely candidate to fertilize the egg.

The solution of the age-old riddle of sex determination, then, has proved to be surprisingly simple. The sex of a child is determined at the time of fertilization by the kind of spermatozoon that happens to unite with the egg cell. This spermatozoon may carry on X chromosome, in which case it will give rise to a girl. If it carries a Y chromosome, it will produce a boy. It is all a matter of chance.

PROBABILITY AND SEX DETERMINATION

Certain facts seem to contradict the chromosome theory of sex determination. In a considerable number of families, all the children are either girls or boys. If one half of the sperm are always boy-determining and the other half girl-determining, why should the Jones family have six boys and no girls and the Smith family six girls and no boys? If we examine the facts in such cases closely, we shall find that such facts agree surprisingly with the theory involved.

Suppose that we toss a coin in the air a number of times, calling the first toss A, the second B, the third C, the fourth D, and so on. When we analyze tosses A, B, C, D, and the rest, we shall find that in about half the cases the coin will land heads up and in the other half heads down. Suppose now that we consider tosses A and B as forming part of a single group and that we pair C and D and all the rest in the same way. We shall find that in about one quarter of the cases there will be two heads, that in another quarter there will be two tails, and that in one half the cases heads will be followed by tails, or tails by heads. That is the way the law of chance operates. In the case of families with two children, you will find that about a quarter of them will have two girls, a quarter will have two boys, and half will have a boy and a girl. If coins are tossed in



The male germ cell has one X chromosome and one Y chromosome. The female germ cell has two X chromosomes. Of the four sex cells formed from the male germ cell, two contain an X chromosome apiece; the other two, a Y chromosome. Each of the female germ cells also yields four cells when sex cells are formed. Each of these contains an X chromosome. If the four male sex cells fertilize the four female sex cells as shown, the result of these unions will be two males and two females.

groups of three, in about one-eighth of the groups there will be a "run" of three heads, and in about one eighth a "run" of three tails. Of families with three children, about one in eight has three boys; one in eight, three girls.

If the letter n stands for the number of children, the probability of having a family of n children all of one sex is approximately $1/2^n$, or $1/2$ to the nth power. This is an approximate formula, not an exact one, since, as we have pointed out, boys are born slightly more frequently than girls. The probability of having n boys is, therefore, slightly greater than that of having n girls. With the aid of this formula, we can predict that about one in sixty-four families with six children will have six boys, and one in sixty-four will have six girls ($1/2^6 = 1/64$).

GENES

Thus far we have been dealing with the chromosomes as if these were the ultimate hereditary units. As a matter of fact, each chromosome contains a number of smaller units, called *genes*. The genes of all organisms appear to be astonishingly similar in chemical composition – they consist of nucleoproteins, which are compounds of nucleic acids and proteins. What, then, makes the human genes differ from those of, say, a dog or a sequoia tree? What makes the genes that modify the eye color in man differ from those that modify the hair shape? Gene specificities – that is, the differences between the genes – reside in their nucleic-acid components. The most important kind of nucleic acid, deoxyribonucleic acid, usually abbreviated DNA, consists of series of four kinds of molecular constituents, or nucleotides, arranged in spirally wound fibers. Now the four kinds of nucleotides can be compared with letters of the alphabet. The twenty-six letters of the English alphabet suffice to build up an infinite number of words, sentences, and paragraphs. This can be done also with only the three "letters" of the telegraphic Morse code

Gregor Mendel performed the classic experiment in heredity. His paper on heredity in the pea plant went unnoticed until the twentieth century.

(dot, dash, gap). Different genes of the same species, such as man, and genes of different organisms differ in the sequences, the arrangements, of the four letters of the genetic alphabet.

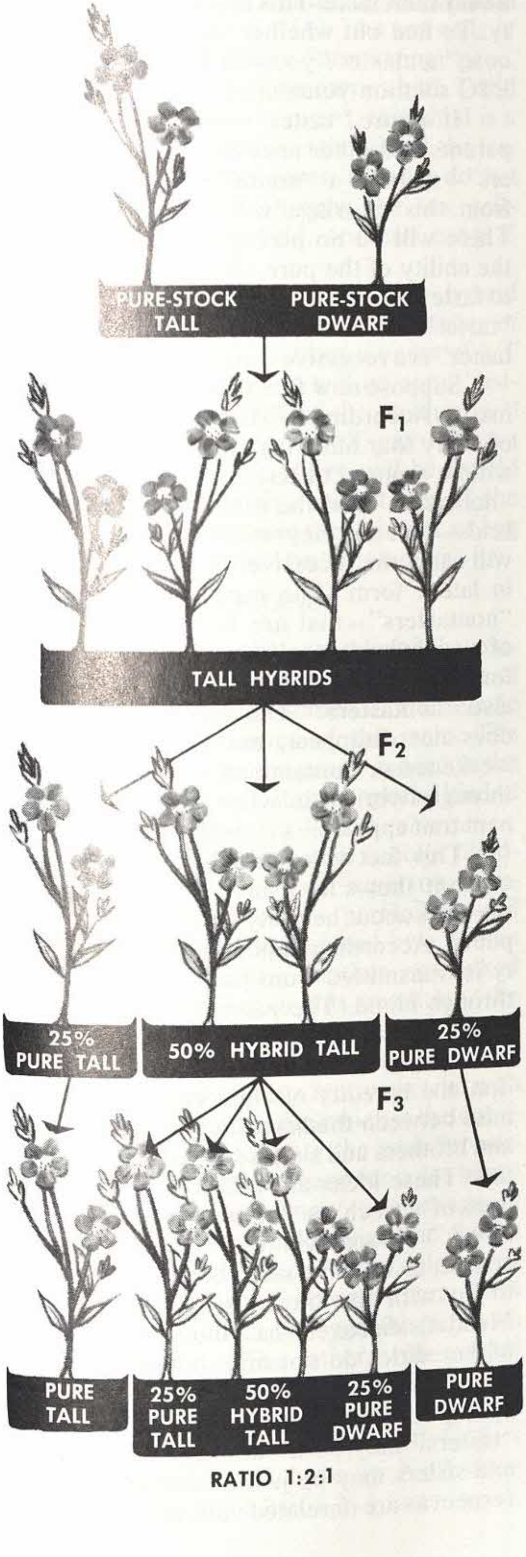
We can think of the genes of a given chromosome as grouped together in a string, each gene occupying a definite place in the string. The genes, together with environments, are responsible for the development of a living body from fertilization, through various stages of fetal life, to infancy, youth, maturity, old age, and death.

What roles do different genes play in this process? The genes are best compared with separate players in a symphony orchestra. A symphony is the product of all the players working together, and yet each player has a different function. When a gene changes, the result may affect various characters or traits. In man, for example, some gene changes influence the color of the eyes, others the skin color, or the shape of the nose, or the speed of blood-clotting, or the intelligence, and so on. Geneticists have been able to draw up chromosome maps for certain species of animals and plants, showing the position of the genes in the chromosomes. They have made a start in drawing up similar charts for human chromosomes.

Curiously enough, the laws governing the inheritance of specific factors, or *characters*, as determined by the genes, were worked out about a century ago by an Austrian abbot long before scientists knew anything about either genes or chromosomes. In the year 1865, Gregor Johann Mendel, abbot of the monastery at Bruenn, read a 20,000-word paper on his experiments in the crossbreeding of common edible garden peas. The paper was published in the proceedings of the society in the following year. In this paper he established certain laws of heredity which have come to be known as *Mendel's laws*. Scientists at that time were not particularly impressed, and Mendel's paper was buried in oblivion for years. It was not until 1900 that it was rediscovered independently by three investigators, working in Holland, Germany, and Austria. It was found later that Mendel's laws applied not only to peas but to other organisms, including human beings.

Before discussing Mendel's laws, let us clarify some basic facts about genes. Ordinarily, each inherited trait, such as the color of eyes or hair in a human being, is controlled by a particular pair of genes working together. These genes are always found in the same relative position on a particular pair of matching chromosomes. Some traits, however, are determined by the interaction of many pairs of genes, located on different chromosome pairs.

When a geneticist speaks of an organism that is *pure* with respect to some trait, that means that both its genes for the trait are identical. As a result, when two pure organisms are crossed, all their offspring will show this trait. A *hybrid* is an organism



that possesses two different genes for the trait in question. If two hybrids are crossed, some of their offspring will show the effects of one gene and some the effects of the other.

Let us suppose that a hybrid individual has one gene C for curly hair and one gene c for straight hair. In this case, the hair will actually be curly, since the gene C is more powerful in determining this trait than the gene c. C is called the *dominant gene* and c the *recessive gene* of this pair. In representing the genetic make-up, or *genotype,* of an individual, capital letters are ordinarily used for dominant genes and lower case letters for recessive ones.

A dominant gene will always show its effects in the physical characteristics, or *phenotype,* of an organism, even though the recessive is present (as in individuals with either genotype CC or Cc). The recessive gene expresses itself only when the dominant is absent (as in genotype cc). Dominance and recessiveness are met with very often in the heredity of man, as in that of other organisms. Yet, as we shall see later on, there are pairs of genes in which neither gene dominates but each modifies the effects of the other.

MENDEL'S LAWS

The first of Mendel's laws is that of *segregation.* When two purebred organisms

Gregor Johann Mendel, whose portrait appears on the preceding page, crossbred common edible peas and established the laws of heredity now called Mendel's laws. Above are shown the workings of the laws of dominance and segregation. When a pure-stock tall plant is bred to a pure dwarf, the first generation of offspring – F_1 – will all be tall hybrids: that is, the gene for tallness will be dominant in them, but the gene for smallness will also be carried. If the members of the F_1 generation are bred together, giving rise to the second generation – F_2 – 25 per cent will be pure tall, 50 per cent will be hybrid tall and 25 per cent will be pure dwarf – a 1:2:1 ratio. This means that the dominant and recessive characters, which were mixed in generation F_1, have now become segregated, or separated. What will happen in the third generation – F_3? If the pure tall plants of F_2 mate, all their offspring will be tall. If the tall hybrids mate, their offspring will show the same 1:2:1 ratio that we noted in F_2; if the pure dwarf plants of F_2 mate, all their offspring will be pure dwarf stock.

with two contrasting characters—such as yellow and green seed color, in the case of peas—are crossbred, the offspring will show only one of these characters. In the case of the yellow-green pair in peas, only yellow will appear in the first generation of hybrid offspring. Yellow is the dominant character. The other character—green—will not be evident in the first generation of offspring, but will reveal itself in a later generation. Green is the recessive character. Suppose that the hybrids showing yellow seed are mated. Of the resulting generation of peas, 25 per cent will have yellow seeds, 50 per cent will be hybrid but show yellow, and 25 per cent will have green seeds. This is known as the 1:2:1 ratio. Thus the dominant and recessive characters that were mixed in the first generation of hybrid offspring have become separated or, as a geneticist would say, segregated.

Mendel's second law is concerned with the *independent assortment of genes.* It states that in cases in which more than one pair of genes are involved, each pair will segregate independently of the others. In peas, for example, tallness and shortness of stem are contrasted characters that segregate in the same way as do yellow and green seed color. Suppose that a tall race with yellow seeds is crossed with a short race with green seeds. In the first generation only the two dominant characters—tallness and yellowness—will appear. If the hybrid forms that result are crossed, out of every sixteen individuals, on the average, nine will show both dominants (tall, yellow), three will show the dominant of one pair and the recessive of the other (tall, green), three will show the other dominant and the other recessive (yellow, short), and one will show both recessives (short, green). This is called the *9:3:3:1 ratio.*

We can illustrate Mendelian inheritance in man by discussing the heredity of a trait that is probably unknown to most people. A weak solution of the chemical known as *phenylthiocarbamide* (PTC, for short) tastes intensely bitter to about 70 per cent of people living in the United States. To the other 30 per cent of the U.S. population, the same solution has no taste at all or only a very faint taste. This is a matter of heredity. To find out whether you are a "taster" or a "nontaster" you will have to try some PTC solution yourself.

If a pure "taster"—that is, one whose parents and other ancestors were all "tasters"—marries a "nontaster," the children from this marriage will all be "tasters." There will be no perceptible difference in the ability of the pure and hybrid "tasters" to taste PTC solutions. In this case, being a "taster" is a dominant trait; being a "nontaster" is a recessive trait.

Suppose now that two hybrid "tasters" marry. According to Mendel's first law, out of every four offspring, on the average, one will be a pure "taster," one will be a pure "nontaster," and the other two will be hybrids—that is, they will be "tasters" but will carry the recessive, "nontasting" trait, in latent form. The pure recessives—the "nontasters"—that are born from crosses of two hybrids are just as pure as those found in families in which both parents are also "nontasters." The recessive heredity does not disappear, nor does it become weakened or contaminated by its passage through hybrids, in whom only the dominant trait appears.

This fact is extremely important because it shows how far from the truth are the ideas about heredity held by the general public. According to popular belief, heredity is transmitted from parents to offspring through blood. The paternal and maternal bloods are supposed to mix and to give rise to a kind of solution. According to this notion, the heredity of children is a compromise between the heredities of the parents, and brothers and sisters have similar heredities. These ideas are reflected in such figures of speech as "blood mixture," "half blood," "blood will tell" and so on. Of course, as we have seen, blood has nothing to do with the transmission of heredity. Mendal's discovery has shown that parental heredities do not mix, but that, on the contrary, they are segregated in the offspring. A child born to parents who are both "tasters" may be a "nontaster." Brothers and sisters may be just as different in this respect as are unrelated individuals.

The sex cells of a pure "taster" contain a gene, T, for tasting PTC. The sex cells of a "nontaster" contain a "nontasting" gene, t. A child of such parents carries both T and t. Since T is dominant over t, this child is a "taster." But—and this is the gist of the law of segregation—the genes T and t do not fuse in the hybrid. Among the sex cells produced by the hybrid, one half carry T and the other half t.

Among the offspring of two hybrid "taster"(Tt) parents, about one quarter of the children will arise from a union of a T egg with a T sperm and will be pure "tasters" (TT). About half of the children will come from the union of a T egg with a t sperm, or vice versa. They will be hybrid "tasters" (Tt). Finally, one quarter of the children will result from the union of a t egg with a t sperm and will be "nontasters" (tt).

SEX-LINKED INHERITANCE

We have seen that one pair of chromosomes is involved in the determination of sex—the XX chromosomes of the female and XY chromosomes of the male. The trait determined by the genes carried in the X chromosomes will show a special kind of inheritance, called *sex-linked inheritance*. One of the traits in question is color blindness, a condition in which a person is unable to distinguish colors, particularly red and green, easily distinguished by a person with normal vision. Another sex-linked trait is hemophilia. In this condition, the blood fails to clot properly. A slight wound is liable to result in fatal bleeding.

Color blindness is a recessive trait with respect to normal vision, which is the dominant trait. Let us indicate the gene for normal vision as C and the gene for color blindness as c. Consider now a marriage in which the mother is color-blind and the father has normal vision. The color-blind mother carries two X chromosomes, both with c genes, and all the eggs she produces will also carry c. The father, with normal vision, has an X chromosome with a C gene, and a Y chromosome that does not carry a gene for color vision at all. Half of his spermatozoa will have an X chromosome and the other half a Y.

The X-bearing spermatozoa fertilizing the egg cells will give rise to daughters, who will carry one X chromosome with C and another with c gene: that is Cc. Since normal vision is dominant over color blindness, these girls will have normal vision, but will harbor the gene for color blindness, c.

If such a woman is married to a normal man (C), all of the daughters will have normal vision, but half of them will harbor the gene for color blindness. Half of the sons will inherit the X chromosome with the gene for color blindness from their mother, and will consequently be colorblind (c). The other half of the male offspring will inherit the gene for normal vision (C).

A color-blind man (c) married to a normal woman not carrying the gene for color blindness (CC) produces children with normal vision only. But while his sons (C) are free from the gene for color blindness, all his daughters carry this gene in a hidden condition (Cc) and will transmit it to half of their children.

If a woman carrying the gene for color blindness married a color-blind man, then half of their daughters would be carriers for color blindness. The other half would be color-blind females. Half of the males produced in this cross would be normal males. The other half would be color blind.

If a color-blind female married a color-blind male, then all of their offspring will be color blind.

Hemophilia is carried in the same manner as color blindness.

COMPLICATIONS IN INHERITANCE

The inheritance of many human traits is not so simple and clear-cut as the ability to taste PTC, or color blindness, or hemophilia. One complicating factor is the fact that, according to the second law of Mendel, different genes are inherited independently. Suppose that a pair of chromosomes carry the dominant gene for brown eyes, which we may call B, and its recessive counterpart, b, which causes blue eyes. The genes T and t, for the ability or inability to taste PTC, are carried in the same person in a different chromosome pair. If a person who has brown eyes and is a "taster"

(BBTT) is married to a blue-eyed "nontaster" (bbtt), the children will have brown eyes and will be "tasters." But they will carry the recessive genes for blue eyes and for the inability to taste PTC. The genes of these children will be BbTt. At meiosis, the chromosomes with the genes for eye color will be distributed independently from those that carry the genes for tasting ability. A marriage of two BbTt individuals may result in the production of four kinds of children—brown-eyed "tasters," brown-eyed "nontasters," blue-eyed "tasters" and blue-eyed "nontasters." Obviously, the situation will be still further complicated if parents carry more than two such latent recessive genes.

Another complication arises when two or three genes located in different chromosomes produce similar effects on the organism. This is called *polygenic inheritance*. For example, there are several genes in man that produce a dark color in skin. Genes that behave in this manner are called *cumulative genes*. Let the genes that darken the skin be called D^1, D^2, D^3, and so on, and the counterparts of these genes, producing no color, d^1, d^2, d^3, and so on. Suppose that blacks carry at least six color-producing genes $D^1D^1D^2D^2D^3D^3$ and that whites carry genes that leave the skin light, $d^1d^1d^2d^2d^3d^3$. The offspring of a first-generation, black-white cross will evidently have the genes $D^1d^1D^2d^2D^3d^3$. It happens that the skin-color genes are neither dominant nor recessive, so that the first generation has, in effect, three color-producing genes, which make his skin color about intermediate between that of a black and that of a white. As we have seen, the sex cells of this cross may carry eight different combinations of skin-color genes($2^3 = 8$):

$D^1D^2D^3$ $D^1d^2D^3$ $D^1d^2d^3$ $d^1d^2D^3$
$D^1D^2d^3$ $d^1D^2D^3$ $d^1D^2d^3$ $d^1d^2d^3$

The cross of two of these first generation types may therfore produce children with as many as six color genes (remember that each set of color genes is paired). Other children born of the pair may have no color genes at all. The children, then, may be as dark as their black ancestors or as light as their white ancestors. Most of them, however, will resemble their parents in skin color. This analysis is oversimplified, because more than three pairs of genes are actually involved. Besides, some of these genes are more efficient color producers than others.

The hair color, stature, weight, shape of the head, and so on are traits that are determined by interaction of several genes each. Their inheritance resembles that of skin color. In the case of eye color, there seems to be one basic color-gene pair that determines the difference between blue and brown eyes and several gene pairs with relatively minor effects. These secondary genes may modify the blue or brown colors by making them darker or lighter, or by restricting these colors to different parts of the iris of the eye.

MUTATIONS

Cells and chromosomes are continually dividing in the body, and the genes are generally exactly duplicated when the chromosomes divide. In relatively rare cases, however, one of the genes of a sex cell will no longer be an exact copy of the original gene. A change of this sort is called a *mutation*. The changed gene is known as a *mutant*. It is known that the rate of mutation in various organisms is increased by radiation with X rays, radium, and ultraviolet light, and by various other conditions.

A small minority of mutant genes may produce desirable effects. The great majority of mutant characters, however, are harmful. They lessen the chances of survival. In the case of humans, harmful mutations are responsible for conditions such as hemophilia and amaurotic idiocy, which is mental impairment coupled with loss of vision. One of the dreaded consequences of nuclear explosions is that they may build up a dangerous degree of radioactivity and that this may add considerably to the number of unfavorable mutations.

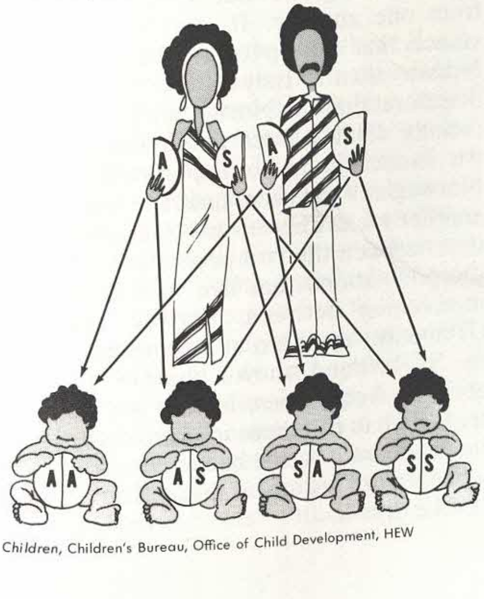
UNDESIRABLE GENES

Many inheritable defects and diseases in man are caused by recessive genes. This is true, for example, in the case of the condition called *albinism.* Those who display this condition – albinos – have a pale skin extremely sensitive to sunburn, pink eyes oversensitive to strong light, and very light, straw-colored hair. Albinos are pure carriers of a recessive gene, a. Many more people carry not only this recessive gene but also a dominant gene, A, for normal pigmentation. These people are entirely unaware that they are carriers. It has been estimated that they are almost 280 times more numerous than the albinos.

Albinism is not a very serious handicap. Other recessive genes, however, are responsible for crippling diseases in man. Like the gene for albinism, they are carried by a number of persons who are quite normal themselves. Marriages between such carriers of defective recessive genes may result, to the utter surprise of the parents, in the birth of afflicted children.

Early in the twentieth century, a group of scientists known as *eugenists* sought to improve human populations by freeing them from defective genes, or at least by reducing the frequency of such genes. The eugenists aimed, among other things, to prevent the carriers of undesirable genes from having children. This could be accomplished either by persuading carriers to abstain voluntarily from parenthood or by sterilizing them by means of a surgical operation.

Sickle-cell anemia is a serious, inherited disease found almost exclusively among blacks. The inheritance odds are shown here. AA is normal; AS or SA carries the trait; SS has the disease. In people with the disease, the red blood cells are an abnormal sickle shape and do not function normally



Children, Children's Bureau, Office of Child Development, HEW

If an undesirable condition is caused by a gene that is dominant over the normal or desirable trait, the measures suggested by the eugenists may be effective. If, however, the undesirable gene is a recessive, the eugenical program will yield results very slowly, if at all. This is because the persons who carry both the dominant gene and the undesirable recessive gene are themselves normal people. Therefore they cannot be identified and sterilized. In the case of albinos, for instance, the sterilization of all the albinos would leave nonalbino carriers of albinism, who are about 280 times more numerous that the albinos themselves, to carry on the gene for albinism. The number of albinos in the next generation would not be appreciably diminished, as far as we can see.

GENETIC COUNSELING

Because many human disorders can be tied to genetic abnormalities, many prospective parents have sought professional help in determining the chances of their offspring being born with a genetic defect. Genetic counseling is advised for many couples who have a history of genetic disorders in their families. Sickle-cell anemia and Tay-Sachs disease are examples of the types of disorders where *genetic counseling* would be a wise decision.

Perhaps we can look forward to the day when these genetic disorders can be diagnosed and treated. Scientists involved in *genetic engineering* hope to perfect the means of removing defective genes from the chromosomes and substituting normal genes in their place.

THE CONCEPT OF RACE

If marriages took place regardless of social and economic status, religious persuasion, and nationality, gene frequencies would become alike throughout the world. This would not mean that all men would

Ray Ellis, Rapho/PR

This young man is an albino. Albinism is a genetic disorder that causes an extreme deficiency of certain pigments in the skin. The gene for albinism is autosomal recessive, so both parents must carry the gene.

become alike. Since gene differences are not leveled off by hybridization, mankind would show even more varied hereditary endowments than is the case today. However, the same diversity of types would be found everywhere. Actually, marriages are not concluded at random, and certain genes are encountered with greater frequency among the inhabitants of certain areas than others.

The gene for albinism, for example, occurs more frequently in a certain Indian tribe living in the jungles of the Isthmus of Panama than in most other populations. There are fewer cases of color blindness among American Indians than among whites. The frequency of the genes for dark skin color is much higher among the natives of central Africa than among people of European origin. The gene for the blue eye color is met with very frequently among the inhabitants of northern Europe, particularly in Norway. It becomes progressively less common as one proceeds southward from Norway, through central Europe, to the Mediterranean countries, and to Africa. It must be kept in mind, however, that some brown-eyed individuals occur in Norway, and some blue-eyed ones in the Mediterranean region and Africa.

Populations differing in the frequencies of their genes are called *races*. The modern idea of race follows from the gene theory. It differs radically from the older concept, based on the notion that heredity is transmitted through "blood." According to this outmoded racial doctrine, the hereditary endowments of a human population become more and more similar generation after generation, provided that no interbreeding with other tribes takes place. Eventually, a tribe becomes a "pure race," whose members are more or less uniform genetically.

Some scientists were misled by this notion into believing that, at some remote time in the past, mankind consisted of an unspecified number of such pure races, whose members were all blue-eyed or all brown-eyed, all tall or all short, and so on.

On the other hand, some people underestimate the differences between members of the human species. The statement was sometimes made, accordingly, that there is no such thing as racial difference. This point of view is also obviously contrary to the facts in the case. It is easy to see, for example, that blond persons are more frequent among people of European extraction than among those descended from Africans, and that they are found in northern more often than in southern Europe.

There is undoubtedly such a thing as race. When we try to classify the different races, however, we run into great difficulty. The trouble is that there are many races and that they are not sharply separated from one another. It is obvious, for instance, that more people have blue eyes in Norway than in Italy. It is possible to say, therefore, that the Norwegian population is racially distinct from the Italian one. Yet we cannot jump to the conclusion that Norwegians represent one race and Italians another race. There is no clear-cut separation between the two populations, because the populations that live in the countries intervening between Norway and Italy (Denmark, northern and southern Germany, Switzerland) show a chain of intermediate gene frequencies. It does not help matters much to call these intermediate populations separate races, because nowhere can a line separating any of these races from the rest be drawn.

We are faced with a dilemma, therefore. It is an undoubted fact that the populations of Norway, Denmark, Germany, Switzerland, and Italy are distinct. It is purely arbitrary, however, to recognize only one, or two, or three, or five, or ten races. It is just as arbitrary to discard racial labels altogether.

HEREDITY AND ENVIRONMENT

The hereditary endowment—that is, the genes that an individual has inherited from his parents—functions in an environment that does not remain constant. A rainy day is followed by a sunny one; summer, by winter; abundance of food, by scarcity. It would obviously be fatal for life on our planet if each kind of heredity could function in only one environment. In reality, organisms are generally able to exist in a certain variety of environments.

The effect of environment upon man and all other living things is obvious enough. As we have seen, the skin color in man is determined by his hereditary constitution. But everyone knows that skin color is also influenced by exposure of the skin to the sunlight. Some individuals have quite pale skin after a winter spent indoors, but develop a dark brown color after a summer spent on the beach. The genes for skin color remain the same in winter and in summer. Yet these genes produce little color in some environments and much color in others.

To say, therefore, that the skin color is determined by the genes is inexact. The skin color is determined by the interaction of heredity (as determined by the genes) and the environment. The heredity of an albino produces no pigment in the skin regardless of sun exposure. Other heredities that occur frequently in what we call rather inaccurately the "white race" show pale skins when seldom exposed to the sun but dark skin after prolonged exposure. Still other heredities, mainly in populations of tropical lands, give more or less dark skin regardless of sun exposure.

Some traits are determined rather rigidly by heredity and do not vary much in different environments. Other traits are much more plastic, or liable to be modified. They are easily altered by manipulating the influences of the environment. The ability to taste PTC, or to distinguish between red and green colors, depends upon the possession of the genes T anc C respectively and has little to do with the environment. A "taster" will cease to find PTC solutions bitter only if his sense of taste in general is impaired by old age or by some accident. A person with normal color vision will cease to distinguish red from green only when his eyesight deteriorates. Stature is certainly inherited, yet children of Japanese immigrants grow taller in the United States than their parents grew in Japan. Skin color is doubtless a hereditary trait, yet it can be modified to quite a considerable extent.

It is a matter of the greatest importance, from the viewpoint of evolutionary development, whether a trait responds to the influence of the environment or is rigidly determined by heredity. Natural selection favors the hereditary endowments that enable individuals to survive and reproduce in a variety of environments. To our ancestors, for example, the ability of the skin to tan was probably important as a protection against sunburn. It enabled them to gather food in intense sunlight. Such an environment might have proved fatal to organisms not possessing this type of adaptation.

The number of different hereditary endowments that exist in mankind is almost equal to the number of people living. We cannot change the genes with which each of us has been born. The eugenists may be successful in persuading, or forcing, the carriers of some grossly defective genes to refrain from passing these genes to posterity. Yet this would not solve the basic problem: how to live in a world in which every human has a different hereditary environment and differs from every other human.

This problem can be solved. For one thing, we shall have to accept and even admire the differences among men, instead of considering them as a curse and a pretext for conflict. We shall also have to provide each member of society with an environment in which he can realize the full possibilities of his hereditary endowment.

GROWTH, DEVELOPMENT, AND DECLINE

by Bentley Glass

Birth is not the beginning of life. It is only a change in the environment that surrounds the individual. It is a rather radical change, to be sure. Yet the growth and development that go on after birth are but continuations and alterations of processes that went on before that time in the embryo and fetus. The saga really begins when the egg is fertilized in the womb.

From a very early age, babies begin to coordinate eye movements. First comes turning the head; then comes focusing the eyes, and third, comes following an object's motion.

Brown University

INHERITANCE

At this real commencement of life, the inherited pattern of a person's growth is fixed, once and for all. Each of the two parents has contributed to the child a set of twenty-three chromosomes—threadlike bodies within each cell. These microscopic threads carry the thousands of genes that determine one's hereditary nature. There are genes for long life, for the color of the eyes, for the shape of the nose, for the size of the feet, and for innumerable other characteristics.

Since the father and the mother each provide one chromosome for each of the twenty-three different chromosome pairs in the human cell, there must be two of every kind of gene, one inherited from the mother and one from the father. But the two genes of any single pair need not be exactly alike. A gene that promotes normal blood clotting, for example, may be paired with one, derived from the other parent, that is unable to provide normally clotting blood. When the two genes in a pair are different, one usually dominates. If a person has one gene for normal blood clotting and one that is ineffective, his blood will clot normally. It will not do so if both genes of this particular pair are ineffective.

Genes and chromosomes, then, are present in the fertilized egg from the very beginning, and they control development all through life. Some produce their effects early, others only in later years. Thus one type of diabetes, as a general thing, shows up after the age of forty. The genes that make a long life possible may not reveal their presence until even later.

The genes represent the potentialities of all growth and development. Yet, since no human being can develop in a vacuum, normal growth and development can take

During the second half of the first year of life, a baby begins to crawl and explore.

Hanna Schreiber, Rapho/PR

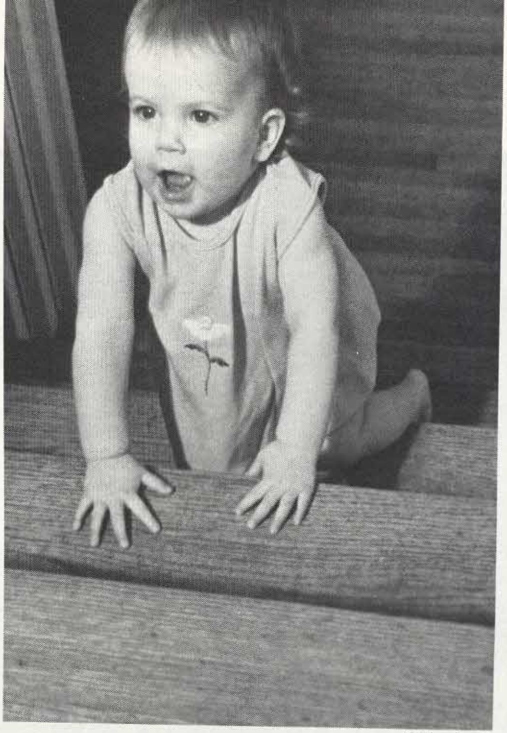
place only in a normal environment. There must be an adequate supply of many sorts of essential things—water, mineral elements, fats, sugars and starches, proteins, vitamins, oxygen, and so on. There must be adequate elimination of waste substances of all kinds. There must be careful control and regulation of physical and chemical conditions, such as temperature, acidity, and the concentrations of substances. Changes in any of these factors may, and indeed will, alter considerably the processes of growth and development.

When we speak of an inherited characteristic, we generally have in mind one that is not readily altered by ordinary changes in the environment, or that we do not yet know how to change—such as eye color, for instance. However, this does not mean that the characteristic cannot be changed at all or that we ought to be fatalistic about such things. For example, diabetes, which in former times was a fatal disease, is inherited—that is, there is a gene responsible for it. Yet injections of insulin will keep it under control. In fact, some day we may even learn how to prevent it from developing at all. So an inherited abnormal condition may well be cured or prevented.

The environment of the unborn baby is highly regulated and very uniform, compared to its surroundings after birth. Hence the features of growth before birth are much the same for everybody, except for the differences that result from different genes. After birth, however, persons show more and more variation because of differences in surroundings, food, care, training, and so on. So, although all a person's potentialities depend upon the genes he has at birth, what will come of these potentialities depends more and more on his special environment as he grows up.

GROWING PROCESS

In its simplest sense, growing means adding living matter to the matter that is already present in the body. Every person is made up of a vast number of tiny cells. Because there seems to be a limit to the size that a single cell can have, a body's growth comes about through the multiplication of the number of cells. Each cell divides into two, and then these grow to their full size and divide in their turn. It takes many successive divisions of the cells to produce a baby from a fertilized egg. By that time, the growing process is almost finished, at least by comparison with what has gone before. The weight of the human body, from ferti-



Gerber Foods

Erika/PR

Sitting, crawling, trying to stand, and hand-eye coordination are major events. They are important for exploring and coping with the baby's environment. Vocalizing is also important.

lized egg to newborn, has multiplied 2,500,000,000 times. It increases only twenty times or so from newborn to adult.

Both brain and voluntary muscle have their full quota of cells before birth, and no new ones are produced after that time, even to replace those that happen to die. In the liver and various other organs, cells practically stop dividing by the time of birth, although they can again begin to do so if a part of the organ has been destroyed. In only a few structures are the cells constantly multiplying in number. Among them are the skin and the blood cells. Red blood corpuscles, for example, can serve as carriers of oxygen for only about eighteen weeks before they break down. Such enormous numbers of them are required that, in the bone marrow where they are produced, some two million of them must be turned out every second of the day and night.

TWO MAIN STAGES

There are two main stages of growth and development. First, there is an *automatic period*. This is followed by a *functional stage* during which development depends upon contact, strain and stress, exercise, and learning and all sorts of experiences. Birth does not represent a dividing line between these two stages, for many automatic steps in development occur after birth. Among them are the change from blue to brown eye color in many persons during childhood, or the regular changes of adolescence in everybody. On the other hand, many functional steps in development are taken before birth. When the unborn baby kicks and turns within its mother's body, it is beginning to make its bones and muscles strong through use.

Because some people are well fed and some are half-starved, because some stay well and others get sick, and because of all sorts of other circumstances, there will inevitably be differences in people's growth and development. These will be heightened by differences in the genes they inherit, for no two people, except for identical twins, have identical genes. Some tend to grow faster, others slower; some, fatter, others leaner.

INFANCY AND EARLY CHILDHOOD

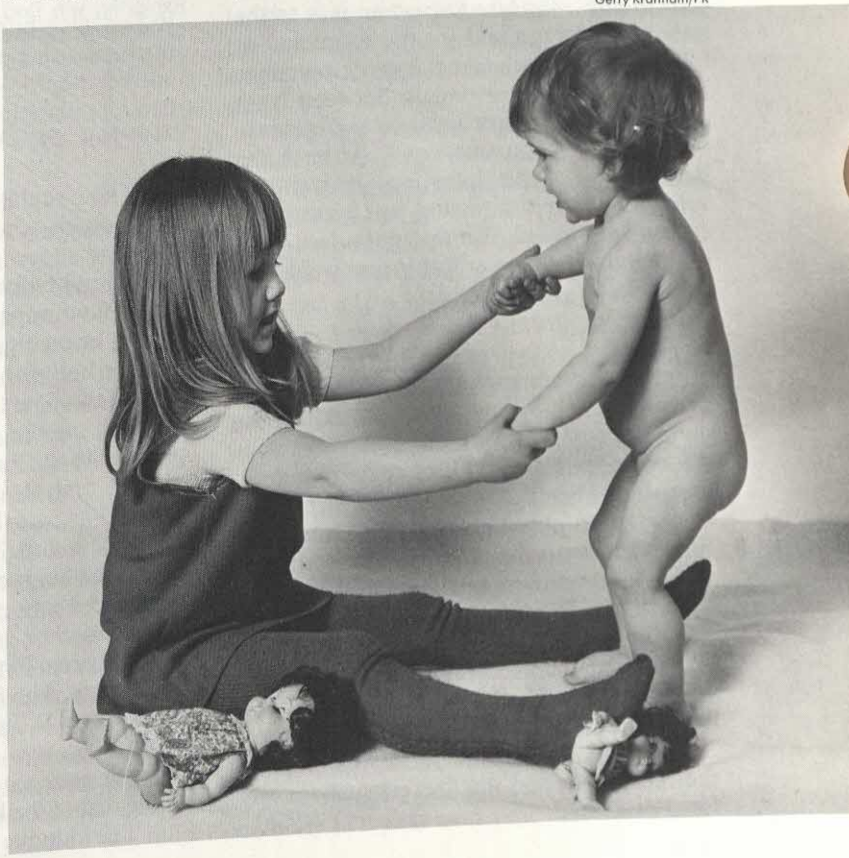
Look at the newborn – the tiny bundle of reflexes, just come into the outer world to grow and develop into an adult. It is helpless at birth, yet it is destined to become skillful in movement and to learn to think. Nothing is more marvelous than the story of its growth.

The very first adjustment after birth has to be that of breathing. The supply of oxygen from the mother has been cut off for some little while and death will come quickly if the breathing is not started. For several weeks before birth, the breathing muscles of the chest, abdomen, and diaphragm have been practicing a bit at inflating the lungs. The shock of the cold outer air as the baby emerges from the mother's body usually provokes a cry that draws air into the lungs. Breathing then starts. For the first year, breathing depends mostly on the abdominal muscles, and it is shallow and rather rapid. After the baby commences to sit up, the thoracic, or chest, muscles begin to assist with the breathing, and it grows deeper and slower. Between three and seven years of age, the adult pattern of breathing is set.

The smaller a body, the more surface it has in proportion to its bulk Since greater surface means more loss of heat, a baby, relative to its weight, loses more heat than a grownup. This means that more food and lots of muscular activity—mostly kicking and squirming—are needed to produce the heat. Because of high heat loss and poorer control over heat production and body temperature, chills are a menace to the newborn.

Body temperature is not well regulated until a child is about two years old, although in this respect each child is apt to follow his own rules. Temperature controls are connected with the development of the thyroid gland, which normally shows a steady rate of growth from birth to maturity. If a thyroid is underactive from birth, a child soon becomes a *cretin.* Growth is stunted to dwarf size. In addition, a puffy fullness of face, lips, nose, tongue, and the skin in general is produced. The intelligence fails to develop normally and the

Gerry Kranham/PR



Toddlers (right) have control over many body functions, as well as improved coordination, but the period from ages 1 to 3 is difficult as far as social growth is concerned. The six-year-old (left) has better control over her fears and can help a younger sister or brother.

child is retarded. Fortunately, if he can be treated with thyroid hormone early enough, he can overcome this condition.

The development of the digestive system is another necessity in infancy. Everybody knows that a small baby cannot eat adult foods, although its digestive organs are further advanced than most of us realize. In the first two years, there is a fivefold increase in weight in the salivary glands. The stomach can hold from ten to twenty times more by the end of the second year. The pancreas and the glands of the stomach and intestines are all ready for action at birth, although their secretions are small in amount. At birth, the weight of the pancreas is only a little more than four per cent of its adult weight. At three years, it has completed one third of its growth.

The liver is relatively large at birth, and although its weight increases about ten times in all, the ratio of its size to that of the whole body diminishes by half. Its early growth indicates how important it is to the infant for storage and for the formation of bile. Both the large and the small intestines just about double in length between birth and full growth, with most of the increase coming in the first two years. At birth the inner layer of the intestines is well developed, so that digestion and absorption are well advanced. But the muscular layers of the intestines are still thin and weak and have a lot of growing to do.

MILK TEETH

At birth, the milk teeth and most of the permanent teeth are already present in the gums, but eruption of the milk teeth does not begin until the sixth or seventh month, as a rule. Then the middle, or central, incisors start to come in, closely followed by the lateral incisors. The lower teeth break through the surface of the gums before the upper ones. The first molars erupt at 12 to 16 months and the canines afterward (16 to 20 months). The second molars are the last of the milk teeth (20 to 30 months). The buds of the permanent teeth already present at birth include all those that replace the milk teeth and the first permanent molars besides.

Sherry Suris, Rapho/PR

Exploring wih Dad. The school-age child asks a great many questions. The powers of observation are sharpened during this time.

INTERNAL ORGANS

The circulatory system has to make a considerable adjustment both at the time of birth and afterward. The lungs receive very little blood before birth, but afterward the whole flow must be passed through them. This is brought about by the closing of the passage between the right and the left auricles of the heart. Thereafter, all the blood entering on the right side of the heart is pumped to the lungs.

At first the baby's blood pressure is low and its heartbeat about twice as fast as that of an adult. The blood pressure slowly rises. The hearbeat becomes slower, losing about 25 beats per minute in the first two years, another 10 by the age of five, and gradually reaching the final rate of about 70 per minute. The heart, like the liver, is relatively large at birth. While its size doubles in the first two years and triples in four years, it does not keep pace with the growth of the rest of the body.

The kidneys are also relatively large at

These four boys are 13 years old. Note the differences in the size and general build of the body.

Mimi Forsyth/Monkmeyer

birth and are quite able to handle the task of excreting the body's wastes. Between birth and one year, they triple in weight. By the end of one year, they have already attained one-fourth of their ultimate size.

CARTILAGE INTO BONE

The skeleton and the voluntary muscles of the body have far more of their growth ahead of them than the heart, liver, and kidneys. The bones of the newborn baby are hardly bones at all. Most of the skeleton is still formed of cartilage, which is softer than bone. Centers of transformation into bone, about eight hundred of them, arise in the cartilages before birth in some cases but in most cases after birth.

In the long bones of the arms, legs, hands, fingers, feet, and toes the earliest center of bone formation in each bone is in the shaft. Not long after birth, secondary centers arise in each enlarged end of the bigger arm and leg bones. These secondary centers of bone formation are known as *epiphyses*. The cartilage between the epiphyses and the main center in the shaft keeps growing rapidly. As a result, the epiphyses are pushed farther and farther apart. Only after the bone has reached its full length, toward the end of adolescence, does the cartilage stop growing, allowing the epiphyses to become firmly attached to the shaft.

The age of a child's skeleton can easily be told from X-ray pictures. For instance, at birth there are no epiphyses in the hand and no bones at all in the wrist, only cartilages. At one year, two centers of ossification (formation into bone) have appeared in the wrist and a number of epiphyses have developed in the hand. Between three and five years of age, all the epiphyses in hands and fingers arise, together with two more centers in each wrist. By five, only one center is still lacking. Girls develop the skeleton more rapidly than boys, though they lag behind in stature and weight in these early years.

On every little baby's head are soft places, called *fontanelles*, where the bones of the skull are still incomplete and soft cartilage covers the brain. During babyhood the skull increases in size very rapidly, the *cranium*, or braincase, doubling in capacity in the first year. The soft spots soon disappear as the cartilage is converted into bone. Even the biggest one has closed by the time the baby is a year or a year and a half old.

The cranium reaches its full size by six years of age. Meanwhile the bones that form the face grow quite slowly. Their growth becomes rapid only as the teens are reached. That is one reason why young children's faces are so different from those of adults.

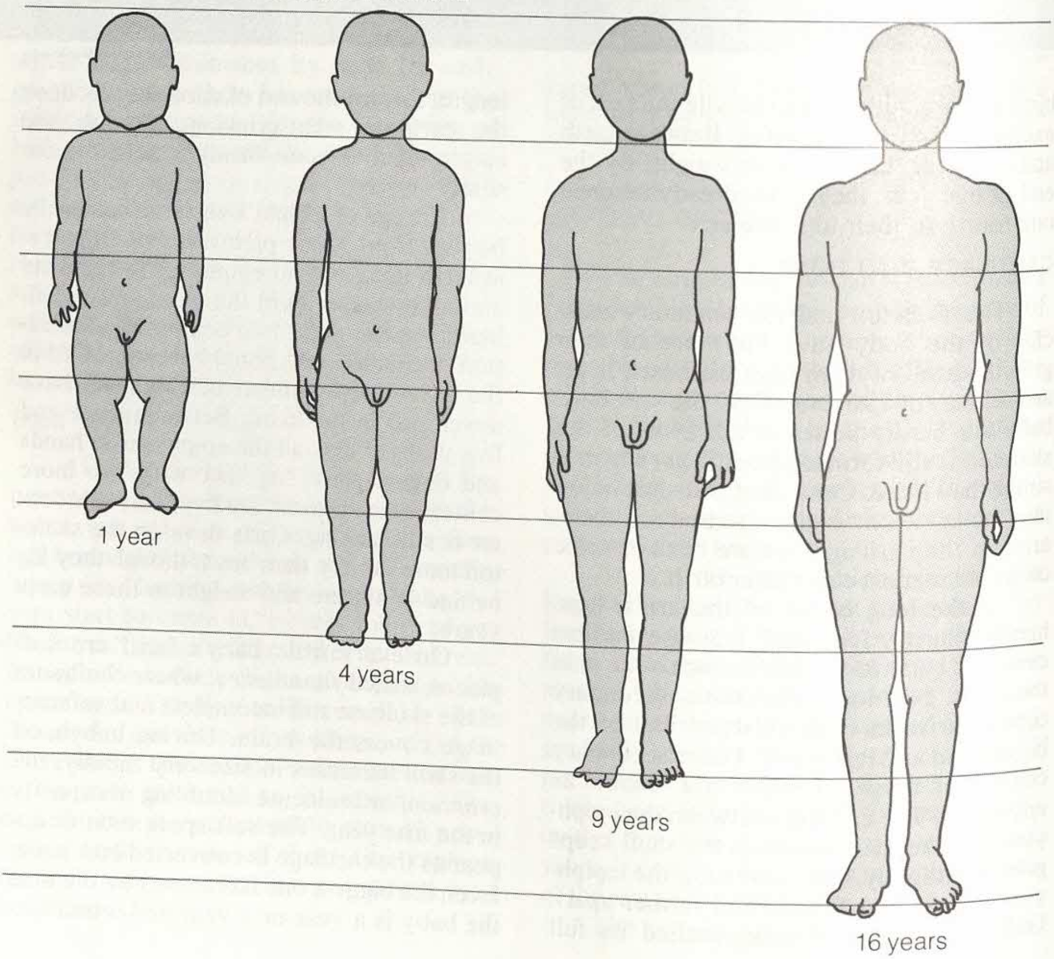
The rest of the skeleton passes through similar changes. At birth the spinal column is largely cartilaginous, but the ribs, needed at once for breathing, are already partly ossified. The typical curves of the spine develop after the baby begins to sit up and to stand. Just as the face and cranium grow at different rates in different periods, so other parts change in proportion, too, because of the differences in their rates of growth. The arms and the legs both become longer in relation to the trunk.

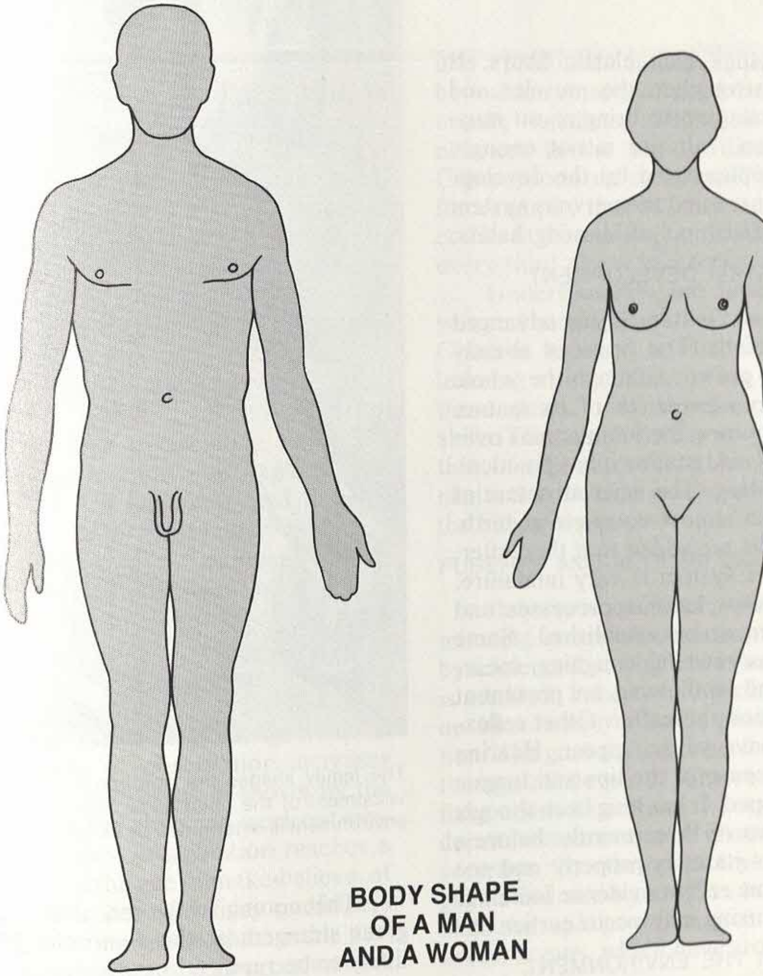
MUSCLE DEVELOPMENT

The voluntary muscles of the body have a great deal of growing to do. Up to four years of age, they keep pace with the rest of the body. Then they begin to grow far more rapidly. Since no new fibers are added, this growth is largely due to an increase in the size of the single fibers.

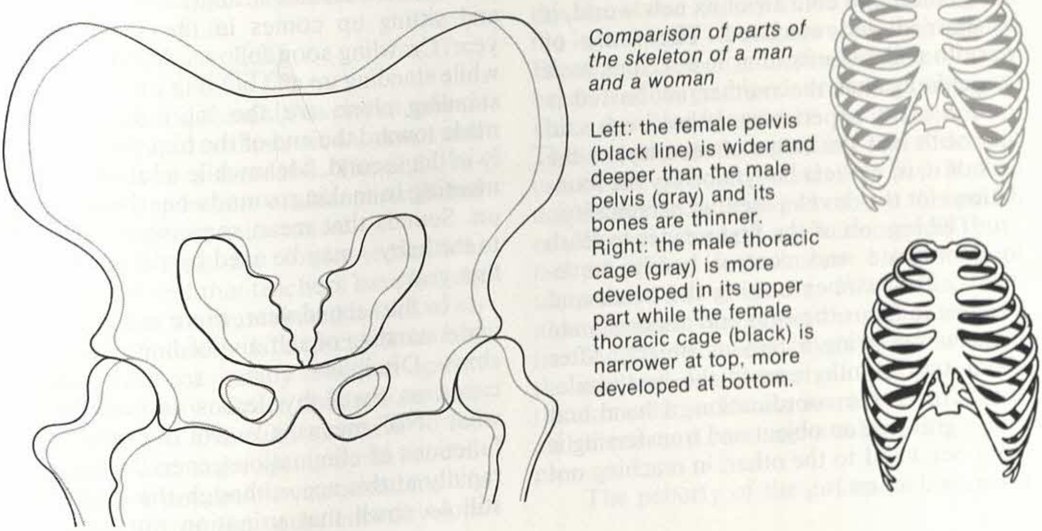
At the start, the eye muscles and those needed for breathing are best developed, and the arm muscles are further along than those of the legs. The ligaments and tendons that attach the muscles to the bones are still poorly developed at birth. The

CHANGES IN BODY PROPORTIONS FROM CHILDHOOD TO ADOLESCENCE





BODY SHAPE OF A MAN AND A WOMAN



Comparison of parts of the skeleton of a man and a woman

Left: the female pelvis (black line) is wider and deeper than the male pelvis (gray) and its bones are thinner. Right: the male thoracic cage (gray) is more developed in its upper part while the female thoracic cage (black) is narrower at top, more developed at bottom.

connective tissues lack elastic fibers. It takes use to strengthen the muscles and their attachments and to bring about muscle coordination. But use is not enough. It must be supplemented by the development of the senses and the nervous system and by the acquisition of learning habits.

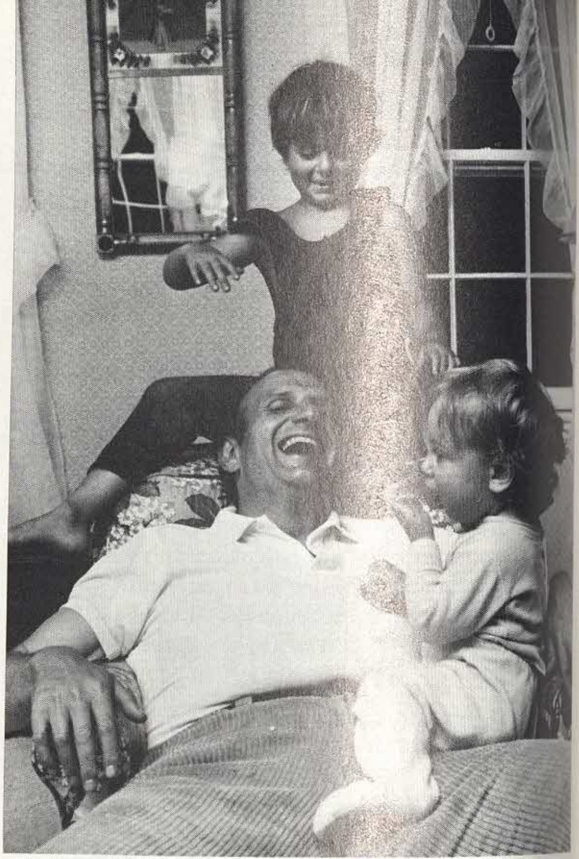
NERVOUS SYSTEM DEVELOPMENT

The nervous system is far advanced physically at birth. The brain is already one-fourth full grown, although the whole body is only one-twentieth of its mature weight. In two years, the brain attains over half its full size, and at nine it has practically finished growing. The inner structure of the brain is also almost complete at birth, and no new cells are added to it thereafter. But the nervous system is very immature. Perceptions, habits, learning processes, and memory still must be established. Some reflexes, such as yawning, coughing, sneezing, sucking, and swallowing, are present at birth or very soon thereafter. Other reflexes, however, have yet to appear. Hearing and the touch sense of the lips and tongue are well developed. It has long been thought that it takes two or three months before a baby can focus its eyes properly and see clearly, but some recent evidence indicates that proper focusing may occur earlier.

DEALING WITH THE ENVIRONMENT

When a baby is ushered into the brightness, noise, and cold air of its new world, it is alarmed and confused. The sense of warmth and security that it develops as it snuggles against the mother and is fed is its first great experience. It has been said that birth and the sense of security, or the lack of it, in earliest babyhood lay the foundations for the development of personality.

The big job of the first year is to learn to coordinate and control bodily movements. First comes turning the head, and learning to focus the eyes and to coordinate them in following a moving object. After about two months comes the first smile. Next comes the coordination of hand and eye in grasping an object and transferring it from one hand to the other, in reaching out for it, and so on.



Katrina Thomas/PR

The family shapes the emotional and social development of the child. How people react to the environment is determined by early social contacts.

The cooing welcome that the baby gives strangers at three months of age is likely to be replaced by distrust and alarm at six months, for it can now distinguish between friends and strangers. Rolling over and sitting up comes in the second half year. Crawling soon follows. Moving about while standing up and holding on and finally standing alone are the big achievements made toward the end of the first year or early in the second. Meanwhile a lot of experimenting in making sounds has been going on. Sounds that mean something—at least to the baby—may be used by the end of the first year.

In the second year, there is a widening understanding of self and of home relationships. Discipline comes to have significance as the baby learns to understand what "No" means. Control over the body functions of elimination generally improve rapidly at this age, although the bladder is still so small that urination must be frequent. The baby is eager to explore everything, but his attention is often and easily diverted. Between one and three years, he learns to focus his interest and attention on things, just as he had learned earlier to focus his vision. He becomes more sociable and dependent on the company of others, while at the same time he is learning in other ways to be more independent. Suspicion of strangers is likely to reach new heights, and worries and fears begin to enter his mind. He is learning fast, progressing from toddling to walking, from babbling gibberish to speaking sentences, from exploring his house to exploring the neighborhood. He learns to feed himself. He experiments with temper tantrums. New emotions, such as jealousy, appear.

From three to six, a new world opens up. Most of the contrariness of the baby just becoming aware of its own individuality now tends to disappear. Curiosity about all sorts of things is a dominant characteristic. This is the great age for questions. Keenness of observation increases steadily at this period, as is shown by the skill with which the child can work out simple jigsaw puzzles. Imagination reaches a peak too. This is the age of make-believe, of imaginary playmates and fairy godfathers who may be as real to the child as his parents. Imitation becomes very prominent. A great deal of experience is gathered through imitating grownups. Playmates become an important part of life.

NEARING ADOLESCENCE

In the period from six to eleven, physical growth, rapid at first, slows down and nearly comes to a standstill. The child becomes less dependent on his parents and develops a sense of self-control.

School begins the formal education. Parents soon find that teachers have largely replaced them as fountainheads of knowledge. Independence is expressed in bad manners and occasionally rebellion against parents' authority. Other children now set the pattern that the children strive to follow. Gangs and clubs spring up as the children strive to get their own community life organized. At this age, conscience develops into a profound emotional guide. There will be sudden onsets of good behavior in the usually heedless child, and attempts at neatness in the usually disorderly child. Compulsions are common. The child feels, for example, that he must not step on the cracks in the sidewalk or that he must touch every third picket in a fence.

Understanding and intelligence develop. Learning now becomes conscious. Children begin to try to learn instead of learning without being aware of the fact. In these years, they develop new reading skills. They cut down the number and duration of the pauses and backward movements that the eyes make as they read along the line of a page.

PUBERTY AND ADOLESCENCE

Puberty is a time of rapid growth, culminating in sexual maturity. It is followed by adolescence, which lasts until adulthood is attained. Puberty and adolescence make up what is known as the period of maturation. The growth in this period, from about the age of eleven to nineteen in girls and from about thirteen to twenty-one in boys, depends in particular on increased hormone secretion by the pituitary and adrenal glands and sex organs. Sex hormones stimulate the rapid growth to mature size of the sexual organs, which have grown very little since infancy.

The very rapid increase in height at this age is due mainly to the lengthening of the legs, for the trunk grows chiefly in girth. Breathing capacity increases. The liver, heart, and large blood vessels double in size; the blood pressure is stepped up. These changes make possible the effective use of the muscles, which also just about double in size, at least in boys, in this period. Physical strength increases rapidly, but lack of perfect co-ordination brings about temporary awkwardness. While the cranium changes very little, the bones of the face lengthen considerably. The features of the adult gradually emerge. The pores of the skin enlarge. Its oily secretion increases and there may be some trouble with pimples.

The puberty of the girl usually begins

at eleven years of age. She then shoots up about seven centimeters or so in a year, changing from plump to slender quite abruptly. The gain of five to ten kilograms per year in weight all seems to go into height. The first outward sign of sexual maturation is the enlargement of the breasts, accompanied by an enlargement of the pelvis. There is a change, too, at the shoulders.

Hair appears on the pubic regions and, usually somewhat later, in the armpits. At thirteen, on the average, the young girl has her first menstrual period, marking the first release from the ovaries of a mature egg cell. She may gain in height in the next few years: about three centimeters the first year, perhaps two centimeters the next, and still less thereafter. Her growth, however, is rapidly slowing down. By the age of fifteen, the adolescent girl is about as tall as she ever will be.

Some girls enter puberty at eight or nine years of age and others only when they are thirteen or fourteen or even sixteen or seventeen. These variations in development may lead to considerable self-consciousness and even alarm on the part of the child. However, there is no physical ill consequence from such variations.

When the boy's puberty sets in, at about the age of thirteen, his shoulders broaden and his muscles fill out. He gains rapidly in height and strength. As his reproductive organs mature, spermatozoa, or sex cells, are formed, and sexual glandular secretions begin. The pubic hair appears early, the hair in the armpits and the beard somewhat later. The larynx enlarges. The vocal cords lengthen considerably and the voice breaks, and after a time it becomes about an octave deeper. At fifteen, two years after the onset of puberty, the boy's growth begins to slow down abruptly. He will gain another two or three inches, but more slowly. By seventeen most boys are full-grown in stature.

During puberty and adolescence, psychological development is no less pronounced than physical development. The sex hormones work a revolution in the attitudes of young girls and boys.

Edna Bennett/PR

An aged woman. In older persons there is a noticeable lessening in size of the jaws and a wrinkling of the skin.

Intelligence continues to develop rapidly in these years. The span and speed of visual perception, on which so much depends in learning, reach their peak at sixteen or seventeen years of age. So does memory; so do speed and accuracy in motor skills and habits. In fact, general intelligence, which shows a steady increase through childhood and early adolescence, improves little or not at all after the age of eighteen. The peak of mental development, at least in the simpler, more measurable qualities, is therefore reached even before the physical prime of the individual has been attained.

MATURITY AND AGING

The human body does not remain at the peak of its powers for very long. A slow but steady decline is the general rule for the years after maximum efficiency is attained. Aging is a normal, not an abnormal process. It cannot be said to begin at any one time. Because the peak of development comes at different ages for different parts of the body, there is no one age of highest efficiency in every respect.

For example, the ability of the lens of the eye to change its shape so as to focus on nearby objects declines steadily from babyhood up to the age of fifty, after which it remains about the same. The thymus gland reaches its maximum size at ten to twelve years of age. Then it rapidly diminishes in size, so that at the age of twenty it has only half the weight it possessed at its largest. It is actually degenerating while the reproductive organs and the voluntary muscles are doing their most active growing.

Muscular strength is greatest in the middle and late twenties, and an athlete is generally (not always) "old" at thirty. The muscles of the back relapse to the level of their power at twenty during the thirties. The biceps reaches this level in the forties, the handgrip in the fifties.

The bones, too, undergo progressive changes. Between the ages of twenty-five and thirty, the bones of the skull make rapid advances toward complete fusion. Later, bones show an increase in mineral matter and a decrease in fibrous organic matter. They become more brittle. Their power to regenerate and knit after a break is gradually impaired. But these changes are slow. Only after seventy does the atrophy of the jaws produce a marked change in the face, particularly after the teeth become loose in their sockets and fall out.

The regulation of stable bodily conditions, such as body temperature and concentration of sugar in the blood, becomes more difficult with the years. The colloids of the protoplasm lose their capacity to take up water. They become less stable and less reactive as they shrink. The healing of wounds is slower. At the age of fifty, wounds heal only half as fast as at twenty.

The digestive organs show the effects of age, particularly in an increasing liability to various disorders. These include gastric ulcers, cancer, and the formation of gallstones. The lungs do not appear to alter much with advancing age, except in elasticity.

There is a lost of elastic tissue in the skin, which becomes thinner as the fat stored just beneath it is withdrawn. Folds and wrinkles appear. The hair becomes gray and sometimes falls out. The nails, especially the toenails, tend to thicken and become deformed as their rate of growth slows down.

The reproductive organs have a rather definite span of activity. In women, menopause, which comes at thirty-eight to fifty years of age, brings to a definite end the capacity to bear children. Like puberty, this change is brought about by the hormones, most probably those of the pituitary and adrenal glands. In men, overall sexual capacity probably declines from early maturity on.

I. Chokhonelidze, Fotokhronika/TASS

Some older people are noted for their longevity, or long lifespan. This man is 102 years old. He comes from Soviet Georgia—a region of longevity.

The heart and blood vessels are most important in the matter of aging, because they are usually first to succumb. "A man is as old as his arteries." Breakdown of the circulatory system causes only 14 per cent of the deaths between the ages of twenty and thirty-nine, but it is responsible for almost two thirds of all deaths after the age of sixty. Deposits of calcium in the heart and arteries, loss of elastic tissue, high blood pressure, heart strain, burst capillaries, blood clots, failure of circulation—these are the common steps in the process. Perhaps the brain and nervous system and the kidneys would hold out indefinitely if it were not for the failure of their elaborate circulations.

There is a steady decrease in the number of taste buds as one grows older, and the sense of smell also declines. Hearing above high C is impaired but below that it hardly changes at all, except in the really deaf. There is a lost of focusing power in the lens of the eye and a decline in the sharpness of marginal vision. In the brain and spinal cord, the white matter suffers more than the gray.

The outstanding thing about aging is the tremendous variation between individuals in its rapidity and its particular course. Long life runs in certain families. The genes undoubtedly play a big part in the later years, just as they do before birth and in infancy, childhood, and adolescence. Even in the same individual, many of the processes involved in aging appear to be quite independent of one another. The nervous system, the respiratory system, and the circulatory system may break down at different periods.

In almost all learning activities there is a slow decline in ability after the age of twenty, just as there is in physical skills and capacities. But if the factor of speed is eliminated from intelligence tests, older persons do just about as well in them as younger ones. In particular skills, many persons over sixty, and even some over eighty, may actually surpass the average persons of their own sex in the prime of life. We should point out, however, that older persons generally hold their own in a subject only if it fits the established patterns and habits of their minds.

Old age must be more moderate than youth, but it can also be rich and fruitful. That is why we should plan in our younger years those interests and activities that will keep us interested in the world around us at ninety. For when our interest in life is gone and only resignation is left, there will be little to keep us here.

DEATH

What we call death represents the breakdown of the complex chemical and physical processes that exist in every living thing. It marks the end of the interchange of substance between the living organism and its surroundings. It brings to a close, too, the constant outlay of energy that is characteristic of life.

Death is really gradual, not sudden. It is true that once a vital system has failed or an overwhelming shock has been experienced, in a few moments the damage done is irreparable. Yet certain tissues may remain alive for a considerable period thereafter. For example, for a number of hours after the death of a person, the still-living cornea of his eyes can be used in transplants.

Death may be premature. The lifespan may be shortened by such factors as the effects of war and peacetime accidents. It may be cut short, too, by disease.

It is true that medical science has made notable progress in the unceasing fight against the many ailments that have afflicted mankind. Consider the communicable diseases whose names once aroused dread: typhoid fever, cholera, typhus, smallpox, diphtheria, yellow fever, and tuberculosis, among others. They have been conquered, or at least held at bay. Nutritional diseases have been unmasked and dealt with: scurvy, beriberi, and pellagra need no longer be feared, if a proper diet can be provided. Progress has been comparatively slow, however, in combating other diseases, such as those involving the heart, blood vessels, and kidneys. The cancers, too, have defied the best efforts of leading scientists. These unconquered killers are likely to strike at any age group, but they are the particular enemies of older people.

Perhaps in another century or so, they too will be vanquished. Then, provided that he can escape the ravages of war, peacetime accidents, and other untoward developments, the average baby will be able to live out the full term of the human hereditary life span. Nobody knows how long this span really is. The Soviet scientist A. A. Bogomolets asserted that the average man should live to be 150, but he may have been unduly optimistic. The age of 80 may well become the average life span. We may possibly advance it somewhat beyond that mark.

Yet in the end we must all die, and others will carry on. Perhaps new minds, new hands, new eyes will develop more effectively than we the potentialities that lie in the ultramicroscopic genes.

OLD AGE

by Helen Merrick

"Grow old along with me, the best is yet to be," wrote the poet Robert Browning. The idea of growing old gracefully has been with us for a long time. Some men and women achieve the feat, loved and honored by younger generations as well as their own. For too many others, however, old age is dreary, useless, and troubled by illness. Yet we know today that the later years can be made rich and productive.

One tool in this effort is *geriatrics,* the branch of medical science concerned with human old age and its diseases. "Geriatrics" comes from two Greek words meaning "old age" and "healing." A broader term, also from the Greek—*gerontology*—is sometimes used. It means the study of physical aging in general, not only in human beings but also in other living creatures and in such nonliving substances as crystals.

No one would deny that to make old age brighter is a worthwhile aim. There are other reasons, however, for the growing importance of geriatrics to society as a whole. In countries where the standard of living is high, more men and women than ever before are living to a ripe old age. In fact, in such countries as the United States, the elderly group is increasing more rapidly than any other. Two thousand years ago, in the Roman Empire, the average length of life was only 23 years, hardly past youth. In the United States around 1900, the average was 47. But consider how life expectancy has leaped within our own century. Today the U.S. average is over 73 years, a gain of about 28 years. The life expectancy is almost eight years longer for women than for men. Since 1900, the total U.S. population has tripled. The age group 65 years and over has more than kept pace; it has increased from about 3 million persons to more than 25 million. The proportion of older persons will probably rise further in future years.

Joe Covello from Black Star

Older people are often troubled by feelings of uselessness. But older people can be and are vital and useful members of the community.

The tremendous gain in life expectancy has come about largely because many of the hazards of childbirth and youth have been practically conquered. One-fifth of the babies born in the United States around 1900 died before they were old enough to go to school. Today, if a child reaches his first birthday, he will almost surely reach high school age. Diseases that attack youth come for the most part from outside the body, carried by microorganisms. With the tremendous improvements in sanitation and medicine's victories over many infectious illnesses, a much greater number of people are surviving into middle and old age. Medicine has still to win over the chronic diseases, which begin silently within the body and are a much greater threat in the later years. Some scientists believe that if human beings could enjoy complete freedom from disease, the normal life-span would be more than 100 years.

The profound shift in the population structure has far-reaching implications. The economic aspect alone has tremendous importance because so many elderly persons have not been able to support themselves. Despite retirement, old age assistance, welfare, and social security payments, older people have a difficult time maintaining themselves in general. Few persons reaching 65 have enough savings to be financially independent.

WHAT IS AGING?

We begin to age from birth and even before. It is all very gradual. Youth does not depart and age arrive at the stroke of midnight on a particular date. The organs of the same person age at different rates. Furthermore, the rate of biological aging varies widely among different individuals. Some persons are able to ward off amazingly the effects of old age. Thus, in one study of old people without disease, comparatively little impairment of bodily organs was found although the subjects were a hundred and more years old.

There is, however, a hazy dividing line on one side of which an organism is considered young and on the other side of which changes appear that indicate aging. Throughout life, there is a building-up, or growth, and a breaking-down, or atrophy. going on in most tissues. Youth exists only while growth exceeds atrophy.

Some living things appear to live indefinitely, as in the case of the one-celled organisms, which, when they have grown to their maximum size, simply divide to form two new young individuals. In one experiment a single ameba went through two hundred successive divisions and was still multiplying merrily at the end of thirteen months. One of the strangest facts of all is that under ideal conditions, living material that ordinarily would age and die will remain young far past its usual span. The most famous experiment to prove this is the one begun by Dr. Alexis Carrel, of the Rockefeller Institute, in 1912. He took a bit of heart tissue from the embryo of a chick and placed it in a nourishing solution. Care was taken that the necessary kind of food, which was taken from other embryos, was provided regularly, waste was disposed of, and no bacteria contaminated the solution. From time to time the tissue was trimmed. It lived and grew until the experiment was deliberately ended in 1946, a period of thirty-four years, though the normal life span of a chicken is about fourteen years.

Joe Covello from Black Star

Employment and mental exercise are important to the physical and mental health of older people. Activity helps keep the mind young.

All the symptoms of aging can be summed up as a gradual decline in the body's powers of self-renewal. Gradually, bones lose their organic material, which is replaced by mineral matter. They become brittle and knit more slowly after a break. Tissues become drier as more fat seeps out of them. It becomes harder for the body to regulate its temperature and to maintain its chemical balance. The senses lose their keenness, although, except for some loss of focusing power, the eye is good for 125 years. On the credit side of the ledger is the fact that the lungs and the digestive system alter comparatively little with age.

HOW TO MEASURE AGING

It is the heart and the blood vessels that first succumb to aging. In fact, breakdowns in the circulatory system account for almost two thirds of the deaths after the age of sixty. The course of such breakdowns usually begins with deposits of calcium in the heart and arteries, followed by loss of elasticity in these organs, high blood pressure, heart strain, burst capillaries, blood clots, and, finally, the failure of the circulation. The brain, nervous system, and kidneys might hold out indefinitely were it not for the failure of the complicated circulation that supplies them. This seems to bear out the old saying that a man is as old as his arteries. Yet hardening of the arteries, or atherosclerosis, alone, is too special a condition to use as a general measure of physical age.

Dr. John H. Lawrence, of the University of California, discovered what seems to be a better measure—that a man is as old as his ability to get rid of nitrogen gas from the blood. At sea level, about 1,000 cubic centimeters of nitrogen gas are dissolved in the body fluids of an adult. The total amount stays the same, but the fluids constantly eliminate the nitrogen molecules they have and take in new ones during breathing. In his experiments, Dr. Lawrence had a group of people of all ages inhale small quantities of radioactive nitrogen as tracer material. He then determined how fast the subjects eliminated nitrogen by collecting the gases breathed out and counting the tagged nitrogen atoms with a Geiger counter. Youngsters of 15 eliminated half the gas in a few minutes, while persons 65 or older took as long as five hours. Another indication that nitrogen-elimination rate is a measure of physical fitness was shown by the fact that subjects in poor physical condition had abnormally slow turnover rates.

WHAT CAUSES AGING?

What aging does is fairly self-evident, but the reason (or reasons) for the decline still eludes us. Among the many theories attempting to explain the causes of aging are several based on genes, the hereditary elements on the chromosomes that affect particular traits. Since it is the genes that direct the formation of proteins in the body, some researchers believe that cumulative mistakes in the formation of proteins result in the death of cells. Another theory holds that the cells of the body gradually mutate. The duplication of these changed cells leads to an accumulation of cells that cannot function properly, causing the body to deteriorate. Still another theory proposes that an individual's life-span is essentially predetermined by that individual's hereditary makeup.

Many biologists suspect that enzymes have much to do with the aging process. Enzymes are exceedingly complex molecules. They are largely built up out of vitamins and minerals, and they act as catalysts in the various chemical processes of the body. That is, they must be present for the chemical reactions to take place, though the enzymes themselves remain little changed or not at all. Without enzymes, no vital process can continue. Consequently, reduction or destruction of enzymes or a loss in their power could account for the symptoms of aging. The little work that has been done along these lines so far does indicate that with age the efficiency of the enzymes decreases. However, most of the research on enzymes has been concerned with identifying them in various chemical reactions and with studying how they work. Discovery of how enzymes change with age therefore would seem to offer pioneering opportunities to scientists.

The foregoing ties in closely with what has been learned about nutrition in relation to later years. Nutrition experts are interested in learning how well food (including oxygen and water) is absorbed and used by the body, as well as the kind and amount of food consumed. They believe that what we eat is closely related to the rate at which we age.

By the time many persons reach the age of 60, their bodies are poor in calcium, iron, protein, vitamin A, and the B vitamins, and these deficiencies have been built up over years. Calcium alone is a sort of jack-of-all-trades in the body. It is essential to bones and teeth, in heart action, and blood clotting. If the blood does not get all the calcium it needs from food, the blood takes what it needs from bones until they become as brittle as toothpicks. Anemia results, with a loss of muscular strength and lowered resistance to infections, if the body does not get enough protein. Without iron, the blood cannot carry life-sustaining oxygen to the tissues.

THIN RATS VERSUS FAT RATS

The foods the older person does not need so much of are sugars and starches

Margot Fuld, from Monkmeyer

Although strenuous physical activity is probably unwise, light or moderate activity is beneficial to older people.

and fats. Cake and candy and gravy merely add kilograms of fatty tissue that must be supplied by extra blood vessels, adding undue strain to the circulatory system. As the famous experiments on rats conducted by Dr. C. M. McCay, at Cornell University, proved, the "thin rats bury the fat rats." Ordinarily, a rat reaches full growth at four months, is elderly at two years, and dies before three. By feeding a group of rats a diet that was low in calories but had enough vitamins and minerals, the period of growth was extended from four months to as long as 1,000 days. In one experiment, the last senile survivor of a group receiving the usual kind of food died at 965 days, though at the same age the animals with a low-calorie diet were still bright young adolescents. Their whole life span was the equivalent of a human life span of from 100 to 150 years, and they were seldom diseased and were much more energetic in every way than their brothers on the usual diet.

Overweight in later years carries other penalties. In addition to the strain on the circulatory system, it is associated with gallbladder disturbances, hernias, and diabetes. In fact, 80 per cent of the cases of diabetes in adults are connected with overweight.

What, then, is a good diet for the later years? In general, it should include a high level of proteins, a low level of fats, only a moderate amount of sugars and starches, and higher than average amount of minerals and vitamins. In terms of breakfast, lunch and dinner, this means: eat plenty of vegetables, fruits, lean meats, fish, cottage cheese, and eggs; eat lightly of cereals, fats, and sweetened fruits; shun concentrated sweets and alcoholic beverages. Drink some milk. However, ordinary milk contains considerable fat and other undesirable ingredients for older people, and now a "geriatric special milk" that is high in protein, low in fat, and rich in calcium, iron, vitamins, and other wanted materials is available.

As we said earlier, there is still tremendous variation among individuals in the rate at which they age and the course aging takes. No two persons who have lived a century or more ever give the same recipe for longevity. So we cannot get away from the fact that some persons inherit stronger constitutions than others. Long life runs in certain families. At the same time, if many of the chronic illnesses that afflict the aged were detected early, they could at least be brought under control if not cured. Unlike the diseases that are more prevalent in youth, which are of short duration, the chronic diseases, as the name implies, are lingering and often result in complete invalidism. The best safeguards against them are thorough periodic examinations, even when the person feels well.

AGING AND HUMAN MINDS

Aging affects the mind as well as the body. There seems to be a very slow decline in learning activities after the age of twenty—at least the speed of learning decreases. But if the factor of speed is removed from intelligence tests, older persons do as well as younger ones, with one important exception. This is that anything that is entirely strange or that upsets established habits is likely to be far more difficult for the elderly. Perception has become slower and the mind cannot unlearn old ways as easily as when it was younger. However, because of the greater grasp gained through experience, many persons past sixty, and even some over eighty, actually surpass in particular skills or capacities the average person of their own sex in the prime of life. The skills that are kept in practice do not decline like those left unexercised. Verdi composed "Falstaff" at the age of 80. Oliver Wendell Holmes was in service on the Supreme Court bench at 90. Titian painted "Christ Crowned with Thorns" at 95. Granted that these were exceptional men, it is still true that years alone need not dull the highest powers of the human organism.

It follows that for society to discard the skills of men and women just because they have reached a certain birthday is a tremendous waste of assets. It is also a tragedy for many of the workers themselves, not only from an economic standpoint but also because it is a symbol of the end of independence and purpose in life. Many of these people later become truly unemployable simply because they have not been employed.

What needs to be done is to judge the worker on the basis of health, ability to produce, emotional attitudes, and personality, and not on his calendar age. Aptitude tests for those over sixty have been suggested, as have factories especially built for older workers who may have a slower reaction time and less stamina but perhaps more patience.

VALUE PLACED ON MATURITY

From the days of the pioneers in North America, the highest value has been set on the period of youthful vigor. We must change this attitude and place greater value on maturity if we are to cope effectively with the economic problems of the aged.

Interwoven with the basic requirements of good health and economic security for satisfactory later years are many other considerations. Older people need opportunities for play as well as work. They need to give affection and have it returned just as much as younger human beings do. Nor does the creative urge lessen with age. In fact, there is no better insurance against boredom in old age than to have acquired an avocation or a hobby in youth or middle age. Many communities are meeting the need for recreational activities by developing special clubs for the aged. A typical center of this sort is self-governed and is open all day. The members work at various arts and crafts, chat together, edit their own magazine, and plan monthly birthday parties and other entertainments. Many older persons have found new interests, and often new friends of their own age, in adult-education classes. Special housing projects for the aged have also been developed.

In this article we have been able to touch on only a few of the many aspects of geriatrics. Questions have been raised that perhaps only years of research can answer. Nevertheless, since so many of us today can look forward to a long life, it is reassuring to know that science has brought up its big guns and is using them in the battle for healthy, active later years.

The aged face many problems in a society still largely youth oriented. However, they often are able to organize effective pressure groups.

HEALTH—AN INTRODUCTION

What is health? The World Health Organization of the United Nations describes health as "a state of complete physical, mental, and social well-being, not merely the absence of disease or infirmity." Perhaps this description is not realistic; after all, people are not a race of super beings.

A far more realistic definition of health is provided by the Joint Committee on Health Problems in Education of the U.S. National Educational Association and the American Medical Association. According to the Joint Committee, health is "a condition in which the individual is able to mobilize all of his resources—intellectual, emotional and physical— for optimum living." What is referred to here is the best possible use of one's assets, however great or small they may be. This is a definition that can apply to the great majority of individuals. It will hold for particularly favored individuals, for those of average or less-than-average physical and mental development, and even for the handicapped persons who have come to terms successfully with their disabilities.

This teen is starting a program of exercise and weight control. It is important to start good health habits early in life.

Wide World

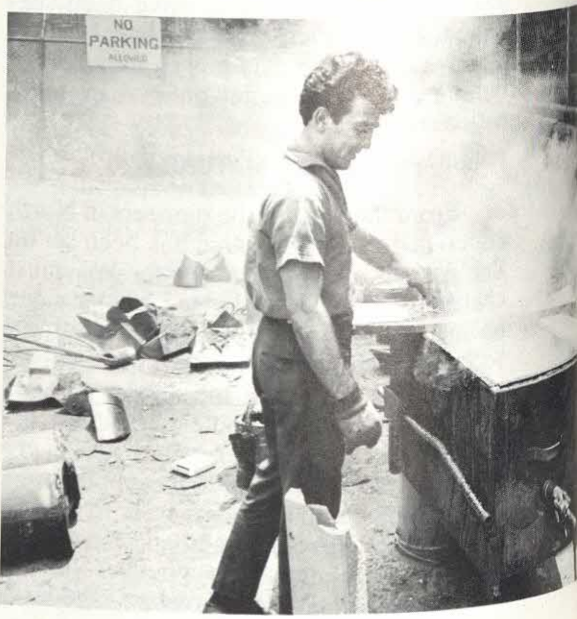
GUIDELINES FOR THE INDIVIDUAL

To a considerable extent, the individual is responsible for his own health. He must establish a definite pattern of healthful living if he is to maintain a satisfactory level of well-being. There are some basic guidelines to follow to reach and maintain this level:

Schedule regular visits to your physician and dentist. They are vital—even if you feel fine. The frequency of visits depends on the individual's age and general state of health.

Keep in tune with your body. Familiarize yourself with the warning signs of illness and seek medical attention promptly if you should become ill. Follow medical instructions carefully, and be sure to allow adequate time for recovery from illness.

Eat a diet that provides a proper balance of proteins, carbohydrates, and fats. This will give you the energy, vitamins,



and minerals that you need for daily activities.

Maintain proper weight for your age and body build. If you need to change your weight, ask your doctor for a diet plan. Avoid crash or fad diets.

Exercise regularly. Muscles are meant to be used. Develop an exercise program and stay with it. For many people, participation in a sport—alone, in pairs, or in a large group—provides needed exercise as well as enjoyment and an opportunity to develop personal relationships.

Obtain sufficient sleep and rest. Individuals vary in their need for sleep, with most adults averaging about seven or eight hours per night.

Avoid situations that can lead to personal injury and obey all safety regulations.

Learn what to do if an emergency arises. Careful and prompt attention in a emergency situation is extremely important in saving lives and preventing serious or permanent injury.

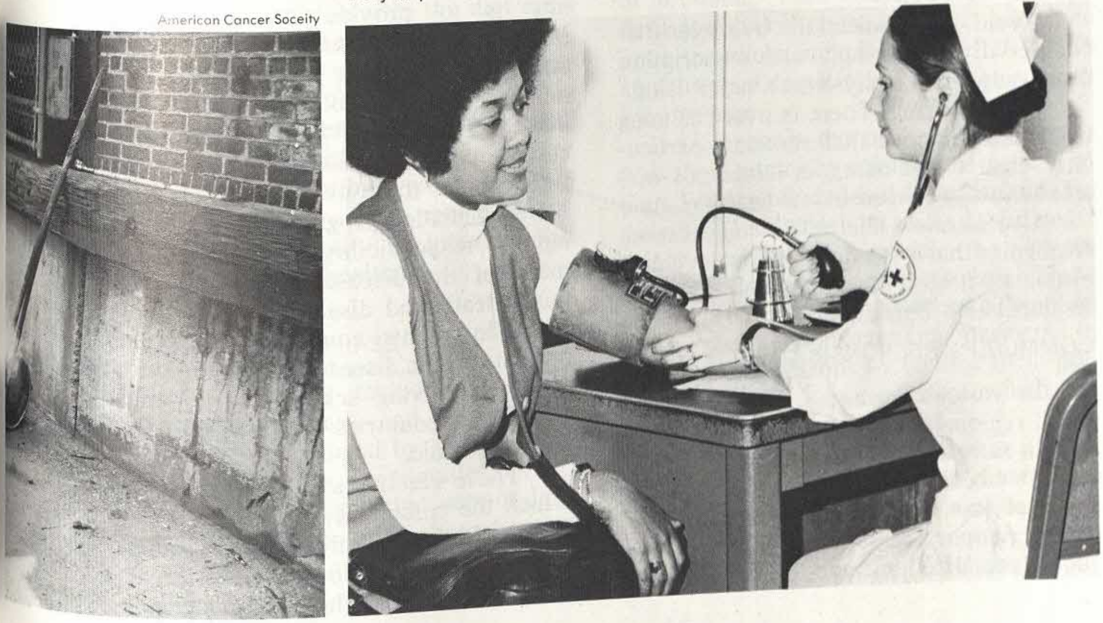
Try to develop a positive outlook on life. A rewarding career, meaningful relationships with other people, time for cultural and recreational activities—these factors and others are important for most people in maintaining a healthy mental outlook—which is essential for health.

Universal/Lactona, a division of Warner-Lambert Company

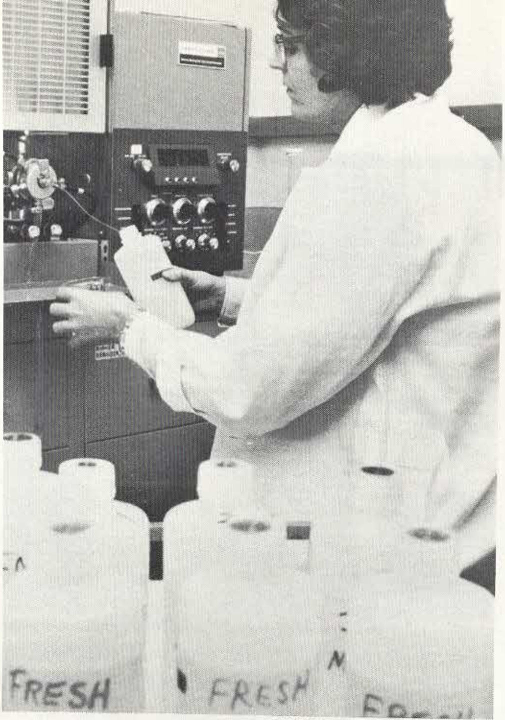
Dental checkups should never be neglected. Healthy teeth are essential to proper digestion and important in maintaining an attractive appearance.

Try to learn how to deal with stress.

Left: this roofer is using a hazardous material. It is the community's responsibility to alert him to the danger and establish guidelines for the use of such materials. Below: a woman receiving a blood pressure checkup. Regular checkups are very important in maintaining health.



American Cancer Soceity



Perkin-Elmer Corp., Norwalk, Conn.

Clean water is necessary for good health. Since the individual usually does not have the means to ensure clean water, the community must supervise water supplies.

Some stress is a part of everyday life, but certain situations – family, school, or work problems – can increase stress. It has been shown that stress has marked effects on the body as well as on the mind. If you have a problem that you cannot cope with, seek professional advice.

Avoid self medication. Use over-the-counter drugs sparingly and prescription drugs only under a physician's supervision.

Stop smoking. There is overwhelming statistical evidence that smoking, particularly cigarette smoking, is dangerous – oftens seriously dangerous – to health.

Use alcohol, if at all, in moderation. Recognize that it is a drug. If you develop a problem with the use of alcohol, seek professional help immediately.

COMMUNITY RESPONSIBILITIES

In various instances, communities – local, regional, and national – must play a role in safeguarding the health of community members. This is particularly true in more or less crowded areas and in areas where people are less self-sufficient and more specialized in their activities.

In rural areas, to cite a familiar example, abundant supplies of fresh air are generally available to all. But what is the city dweller to do when the available air supply is polluted by chimneys belching smoke and by streams of automobiles emitting harmful gases through their exhaust pipes? Steps will have to be taken by the community to stop or at least control the outpouring of smoke from chimneys and to devise methods for preventing harmful automobile-exhaust gases from polluting the atmosphere. Again, in modern city living, water supply and waste disposal cannot be left to the individual. Water must be brought in, sometimes from many kilometers away. The community must provide effective sewage disposal and garbage collection. Housing facilities must be adequate.

Various other community services are required. Adequate food and milk supplies must be assured; there must be competent inspection of these supplies. The community must be policed in order to insure personal safety. Traffic laws must be enforced, and industry monitored so that workers are not exposed to undue hazards.

The community must also provide hospitals and clinics. At-home care and mobile health units are also often essential.

An all-important duty of the community is to provide health education. Many communities help educate the public and maintain health by providing mobile units that visit schools and neighborhoods informing people of the warning signs of certain common diseases and providing free tests for these diseases.

Vaccination programs are also a community responsibility. Vaccines against many of the diseases that once caused much death and disability are now available. In many countries, vaccinations against specific diseases are required for all children entering school and for people traveling to countries where certain diseases are endemic.

These are but a few of the areas in which the community must play a role in health. For more information about community activities, contact your local, regional, and national health agencies.

1959, Parke, Davis and Co.

In the 1750s, Scots surgeon James Lind treated sailors suffering from scurvy. His cure—the juice of citrus fruits. Later, it was found that vitamin C prevented the disease. This vitamin is found in citrus fruits.

VITAMINS

A diet consisting entirely of the so-called primary food substances—carbohydrates, proteins, fats, inorganic salts, and water—would provide us with ample stores of energy and would build abundant body tissue. Yet by itself such a diet would be altogether inadequate. Any human being following it for any length of time would inevitably sicken and die.

To assure good health, the diet must also include a certain number of accessory, or additional, factors called *vitamins.* They promote necessary chemical reactions in the body, when present in small quantities. Only minute quantities of vitamins are necessary to keep the body in good health. Mistakenly, however, many people believe that twice the quantity of vitamins will make them twice as healthy.

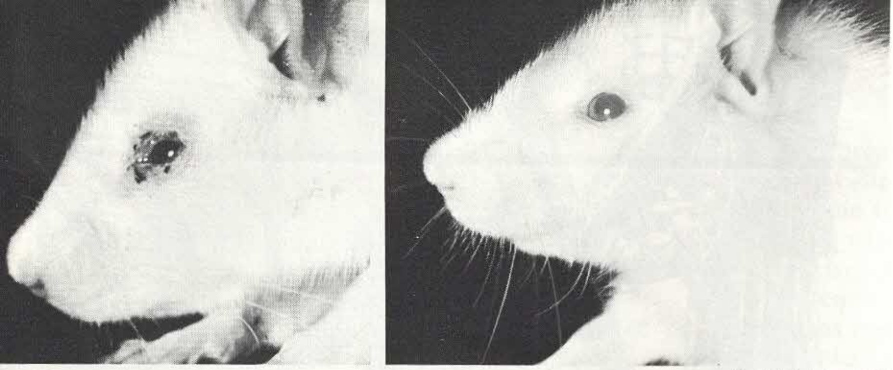
DEFICIENCY AND DISEASE

Many diseases, including beriberi, scurvy, night blindness, and pellagra, are now known to be caused by lack of these essential food factors. As a matter of fact, people realized long ago that certain deficiencies in the diet can bring about disease. They knew, for example, that when fresh fruits and vegetables were lacking on long sea voyages, sailors contracted the dangerous disease known as *scurvy.* This disease could not be cured until fresh fruits or vegetables were once more available.

Many people confirmed this during the 17th and 18th centuries. Among them in the 1750s was a Scots physician, James Lind, who showed that a person could prevent scurvy by drinking lime juice. After years of prodding, Lind finally persuaded the British Admiralty, in 1795, to add lime juice to sailors' rations. Thereafter British ships carried ample supplies of the juice on long voyages.

A pioneer in the study of the vitamins was the Dutch physician Christiaan Eijkman. While stationed in the Netherlands Indies (now Indonesia), he studied the disease called *beriberi,* which attacks the nervous system and often causes death. In 1897, he announced that he had produced a crippling disease, closely resembling beriberi, in chickens and pigeons by feeding them polished rice, which is rice from which the outer coat has been removed.

Later he had cured the birds by putting them on a diet of rice bran. He came to the conclusion that beriberi was caused, not by some harmful germ, but by something that was lacking in the diet. We know today



Far left: a rat suffering from xerophthalmia, a disease of the conjunctiva and cornea of the eye. The cause is a vitamin-A deficiency. Near left: the same rat, after 8 days of treatment with vitamin A; the disease is cured.

The Upjohn Laboratories

that this "something" was one of the vitamins: thiamine, or vitamin B_1.

In 1906, the British nutritionist Sir Frederick Gowland Hopkins showed that when rats were fed a special diet, they needed certain substances found in milk solids in order to remain healthy. Hopkins gave the term "accessory factors" to these substances, whose nature was unknown.

A FACTOR IN FOOD

In 1912 the Polish chemist Casimir Funk recognized the antiberiberi factor in rice husks. He called it a "vitamine" because it was an "amine necessary for life." ("Life" is *vita* in Latin.) The name "vitamine" came to be applied to many accessory food factors. After it had been discovered that not all of them were amines, the "e" in vitamine was dropped.

For several years, only two accessory food factors were recognized: the fat-soluble vitamin A, which cured certain eye diseases, and the water-soluble vitamin B, which prevented beriberi. Later, another factor was added: vitamin C, which prevented scurvy.

As time went on, researchers came to realize that the accessory food factor called vitamin B was really not a single substance but a group of vitamins. These came to be known as the B vitamins, or the B complex. To identify the separate vitamins of the B complex as they were isolated, subscripts were then added, such as B_1, B_2, up to B_{12}. The list of vitamins continued to grow, and other letters of the alphabet were assigned to them. In the course of time, it was recognized that some of the newly discovered vitamins were really identical with accessory factors that had already been isolated and described. Other supposed "vitamins," such as choline and inositol, came to be regarded as body-building materials rather than as accessory factors, particularly because they are needed by the body in such large quantities.

In recent years, the tendency has been to assign chemical names rather than letters of the alphabet to the vitamins. For instance, nutritionists generally refer to B_1 as thiamine and to B_2 as riboflavin. In some cases the letters formerly assigned to vitamins have been dropped entirely: biotin has been substituted for vitamin H; folic acid for vitamin M. There will probably be other changes in vitamin names.

In order to inform the public about the daily amount of vitamins that is required for good health, the U.S. National Academy of Sciences has made specific recommendations. These are known as Recommended Dietary Allowances (RDA). The RDA's are given in milligrams (1/1000 of a gram), in micrograms (1/1,000,000 of a gram), and in International Units (I.U.), which is 1/40 of a microgram. As you can see, the RDA's are very small; for example, a milligram is only 0.00003 ounce. RDA's are frequently listed on food cartons and vitamin-pill bottles.

VITAMIN A

There are really several vitamins A. The best known are retinol, from animal tissue, and carotene, from plant tissue. Carotene is actually a previtamin; it is converted to vitamin A in the small intestine. Each molecule of vitamin A contains twenty atoms of carbon, thirty of hydrogen, and one of oxygen, or, as a chemist would write it, $C_{20}H_{30}O$. This accessory food factor is stored in the liver.

Vitamin A is necessary for the growth and health of human beings. It is required for the proper functioning of the epithelial cells—the ones that cover the surface of the body and that line its cavities. If vitamin A is missing from the diet, a serious lack of vitality develops. Also, epithelial cells become thick and drop off. The condition sometimes occurs in the epithelial cells of the conjunctiva—the mucous membrane lining the inner surface of the eyelid and covering the forepart of the eyeball. This may lead to the disease called *xerophthalmia* and in extreme cases may cause blindness.

In an experiment carried out by the U.S. National Cancer Institute in 1979, vitamin A was linked even closer to problems of the skin. It was shown that the most severe and scarring form of acne was cleared up by treatment with a synthetic variation of vitamin A.

Lack of vitamin A in the diet may also lead to *night blindness*—inability of the eye to adjust itself to dim light. For example, if a normal person is driving at night, he sees a wide stretch of road after the headlights of a car coming from the opposite direction have passed him. Under similar conditions, a person deficient in vitamin A will be barely able to see a meter or so ahead.

Vitamin A along with vitamins D, E, and K are stored in the body fat and do not dissolve in water. They are not eliminated by the body, as in the case of vitamins B and C.

Among the best natural sources of vitamin A are fish-liver oil, butter, and the liver fat of many animals. Fruits and vegetables do not contain vitamin A. Carrots, squash, sweet potatoes, pumpkins, apricots, spinach, tomatoes, prunes, cantaloupes, bananas, peaches, and greens yield carotenes.

The RDA for vitamin A for a normal adult is 5,000 International Units (I.U.), which is a very small amount. Children require less, and pregnant and nursing women require somewhat more.

In most cases, vitamin-A deficiency is not caused by faulty diet. It may come about when the body is unable to absorb the vitamin in adequate quantities as a result of such diseases or conditions as chronic diarrhea, prematurity at birth, and excessive use of mineral oil. In all such cases, large doses of the vitamin must be given in order to restore bodily tissues and to build up adequate stores of the vitamin.

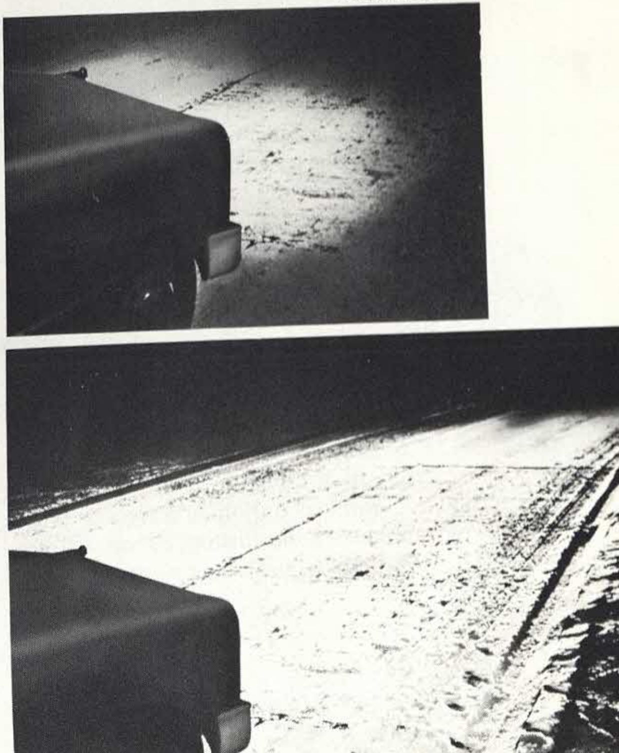
Too much vitamin A causes headache, nausea, and irritability. More severe ailments caused by excess vitamin A include growth retardation in children, enlargment of the liver and spleen, loss of hair, rheumatic pain, and disturbance of the menstrual cycle.

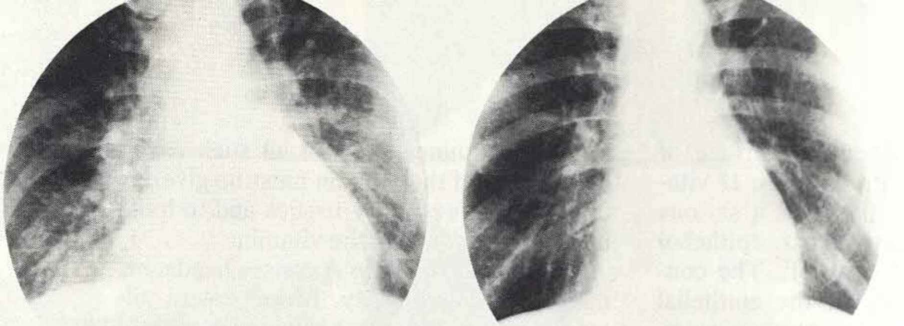
B COMPLEX

The B vitamins, or *B complex*, are a group of water-soluble substances which have certain functions in common but which are not related chemically. These vitamins are often found together in foodstuffs. The members of the group are thiamine (vitamin B_1), riboflavin (vitamin B_2), niacin (nicotinic acid), pyridoxine (vitamin B_6), pantothenic acid, biotin, folic acid, and vitamin B_{12}(cyanocobalamin, the antipernicious-anemia factor).

Top: a person with night blindness, a vitamin A-deficiency disease, can see only a short distance of road in front of him. Bottom: the normal individual can see a far greater stretch of road in front of him. Obviously, the deficient individual is endangering his health in more ways than one.

The Upjohn Laboratories





Left: X ray showing an enlarged heart due to thiamine deficiency. Right: after 3 weeks of treatment with thiamine, there is a marked reduction in heart size.

Henry Field, Jr.

THIAMINE

Thiamine, or B_1 ($C_{12}H_{18}Cl_2N_4OS$), is a crystalline compound with a yeastlike odor. This vitamin is stored in the liver and heart and, to a lesser extent, in the kidney and brain.

Thiamine is required for normal digestion. It is a requirement for growth and normal functioning of nerve tissue and for normal fertility and lactation in women.

Beriberi, a disease of the nervous system, is the result of thiamine deficiency. There is accompanying loss of appetite, fatigue, wasting away of the muscles, digestive disturbances, poor assimilation of food, and loss of weight. In serious cases, paralysis may set in and death may result from its lack.

Other deficiency symptoms are pains in the legs, body swelling, heart problems, and growth retardation.

Thiamine deficiency is especially prevalent in the Far East because polished rice makes up so large a part of the diet in that area. The deficiency is not particularly serious in the United States, Canada, and Europe, except among those who drink too much liquor, indulge in food fads, or eat poorly prepared foods. Dysentery and various other diseases of the digestive system may interfere with the absorption of thiamine and may thus bring about a serious deficiency of the vitamin.

Rice bran and wheat germ are particularly rich in thiamine. A diet containing large amounts of unpolished rice or whole wheat bread should furnish adequate quantities. Oatmeal, peas, beans, peanuts, and lean pork are also good natural sources. Most unprocessed foods, such as whole wheat, brown sugar, and brown rice contain all the thiamine and other vitamin B's that the body can use.

Some people claim that consuming large doses of vitamin B_1 prevents mosquitoes from biting them. There is no evidence for this, however. This idea may come from the fact that individuals suffering from severe reactions to mosquito bites may get relief from doses of vitamin B_1.

The minimum daily thiamine allowance of the normal adult is 1.2 milligrams. In serious deficiency, a dose of up to 100 milligrams daily may be prescribed.

RIBOFLAVIN

The vitamin called riboflavin, or vitamin B_2 ($C_{17}H_{20}N_4O_6$), forms part of a yellow enzyme that is found in every living cell and that has to do with cell respiration. Reserves of the vitamin may be accumulated in the liver and kidney, but these reserves are quickly used up. Among the chief sources of the vitamin are eggs, liver, the legumes, tomatoes, and various fruits.

Deficiency in riboflavin affects growth. It also leads to splitting of the skin around the mouth, swelling of the tongue, impairment of vision, and dermatitis, a skin disorder. The recommended daily allowance for adults is 1.7 milligrams.

A diet deficient in riboflavin is almost always deficient in other B vitamins as well. The treatment for the deficiency, therefore, calls for a sizable dose of riboflavin (10–20 milligrams daily), supplemented by all the other B vitamins.

NIACIN

The enzyme system concerned with the transportation of hydrogen in living cells contains the vitamin niacin, or nicotinic acid, ($C_6H_5NO_2$) and the derivative niacinamide ($C_6H_6N_2O$), which performs the same functions as niacin. Niacin has been known to chemists for over a hundred years. It was first prepared in 1867 by treating nicotine with nitric acid. The resulting compound was called nicotinic acid. It was not until 1937 that it was discovered that this acid is a vitamin and that deficiency in the substance leads to the disease called *pellagra*. Thereafter the vitamin was called niacin, a more sales-oriented name than nicotinic acid.

The niacin-deficiency disease pellagra was particularly common in Italy, Spain, Rumania, and the southern United States, among people who lived on white flour, white sugar, white rice, corn grits, and pork fat. Pellagra is characterized by redness of the skin, soreness of the mouth, loss of weight, diarrhea, and mental disorders. If it is not treated in time, it may result in insanity and death. This picture has been changed through education. People in these areas now eat enriched flour and cereal, whole wheat flour, and peanut butter.

Niacin is found in such natural substances as red meats, liver, yeast, milk, eggs, wheat germ, peanuts, peas, and beans. Niacin and niacinamide are produced synthetically and placed in enriched foods. They are also sold as pills.

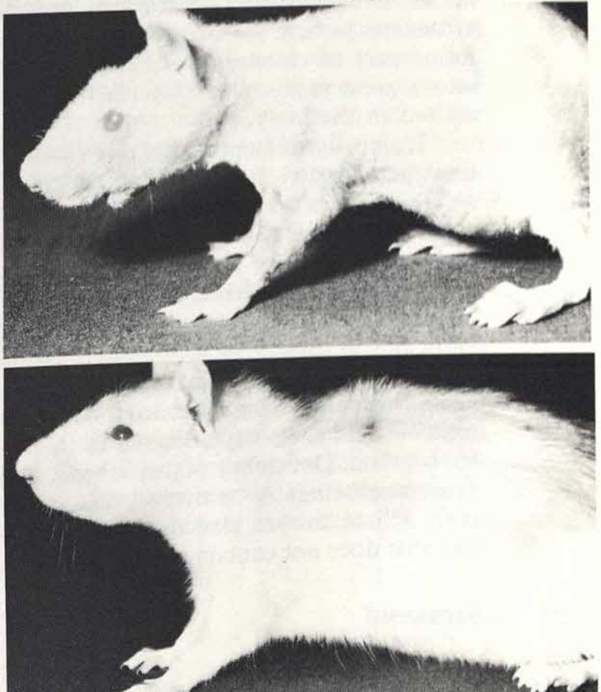
It is believed that the daily niacin need increases with the number of calories consumed. For normal adults, this amounts to about five milligrams per 1,000 calories. People engaged in normal activity in a temperate climate would require up to 19 milligrams daily.

It may be necessary to give as much as 500 milligrams of niacin or niacinamide daily in treating lesions—breaks in the skin—due to pellagra. Generally, when niacin is given to patients, there is a noticeable improvement in their condition within twenty four hours. Another source of niacin comes indirectly from fish. For example, a 250-gram portion of fish contains about 450 milligrams of tryptophan, an essential amino acid. The body then converts the tryptophan to about 7.5 milligrams of niacin.

PYRIDOXINE

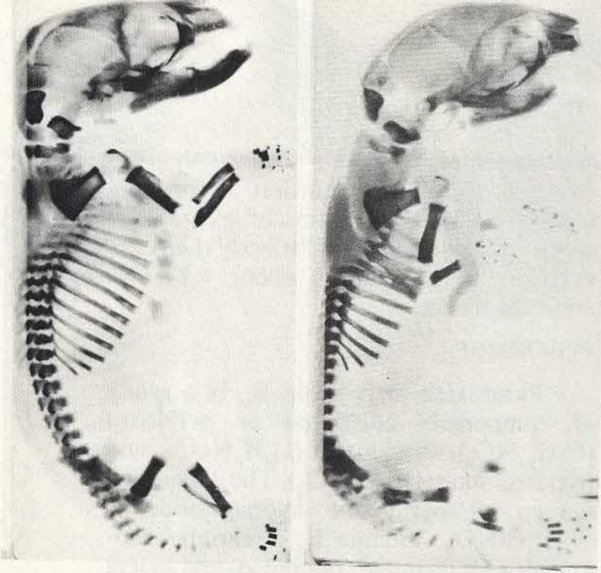
Pyridoxine, or vitamin B_6, is a group of compounds composed of pyridoxol ($C_8H_{11}NO_3$), pyridoxal ($C_8H_9NO_3$), and pyridoxamine ($C_8H_{12}N_2O_2$). The compound known as pyridoxine hydrochloride is $C_8H_{12}ClNO_3$. Vitamin B_6 is closely associated with thiamine, riboflavin, and niacin in nature.

It is believed that pyridoxine has to do with the maintenance of the normal state of the skin, nerve functions, and growth. It is essential for amino acid metabolism. The daily requirement of the vitamin is two milligrams, with larger quantities necessary during pregnancy. Pyridoxine is also helpful in the treatment of radiation sickness and the nausea and vomiting of pregnancy.



Top: this rat has severe riboflavin deficiency. Its growth has been retarded and it is suffering from dermatitis, an irritation and inflammation of the skin. Bottom: after two months of treatment with riboflavin, the rat shows no sign of its original deficiency. Growth has resumed, and the sores on the skin have cleared.

Both photos, The Upjohn Laboratories



Josef Warkany

Left: stained skeleton of a normal newborn rat. Right: similarly prepared newborn rat, showing signs of abnormal prenatal development. The abnormal rat's mother was riboflavin-deficient. Note the bone malformations.

Vitamin B_6 is abundant in liver, eggs, yeast, and numerous other common foods.

In 1978, the *American Journal of Psychiatry* published the results of a strictly controlled study of the treatment of autistic children with large doses of vitamin B_6. The vitamin improved the condition of 11 of the 15 children. (Autism is a severe mental disorder that prevents a child from reacting to its environment.)

PANTOTHENIC ACID

Pantothenic acid ($C_9H_{17}NO_5$) is found in all living tissues. (*Pantothen* means "from everywhere" in Greek.) This vitamin forms part of *co-enzyme A*, which enters into a great many necessary chemical reactions in the body.

If animals are deprived of this vitamin, they fail to grow, their hair changes color, and there are breaks in the skin. In extreme cases, the hind legs may become paralyzed and death may take place suddenly. Diets enriched with pantothenic acid have greatly increased the life span of experimental animals.

An adequate amount of pantothenic acid is provided in unprocessed foods. Pantothenic acid is also synthesized by intestinal bacteria. Deficiency of pantothenic acid in human beings on a normal diet is not seen. If humans are placed on an artificial diet that does not contain pantothenic acid, headache, fatigue, poor muscle control, cramps, and nausea will appear.

It is not known how much pantothenic acid human beings need in their daily diet. When the vitamin is given with other accessory food factors in treating dietary deficiency, the dosage is generally ten milligrams of calcium pantothenate.

Liver, yeast, eggs, meat, dairy products, molasses, broccoli, and fruits are important sources of pantothenic acid. The richest known source is royal jelly, the food fed to the queen bee by worker bees.

BIOTIN

In 1916, it was discovered that if animals were fed a diet of egg white, they lost weight and developed abnormal posture and gait. If the diet was continued for any length of time, they died. Somewhat later, researchers found that certain foods contain a substance that counteracts the poisonous effects of egg white. It was learned in 1931 that people also need the anti-egg-white factor. It was named "vitamin H."

Vitamin H was isolated for the first time in 1940. It was found to be identical with biotin, a substance that had been recognized in 1935 and that had been described as necessary for the growth of yeast. Thereafter the name *biotin* replaced vitamin H. Feodor Lynen of Germany received the Nobel Prize in Physiology and Medicine in 1964 because, among other things, he showed the part played by biotin in the metabolism of fatty acids.

Biotin ($C_{10}H_{16}N_2O_3S$) occurs widely in foods and is also synthesized by bacteria in the intestine. It is so potent that only infinitesimal quantities are needed. The daily human requirement is not known. However, biotin deficiency is not likely to occur even in greatly restricted diets that do not include egg white. Of course, if a person went on a diet made up to a large extent of raw eggs, he would be inviting trouble.

The late U.S. nutritionist Norman Jolliffe told about an Italian laborer whose diet consisted chiefly of raw eggs (six dozen weekly), washed down by quantities of wine. For years he had suffered from dermatitis and conjunctivitis, and the doctors he had consulted had not been able to help him. He was soon restored to health after he stopped eating raw eggs and adopted a more varied diet, supplemented with injections of a biotin derivative.

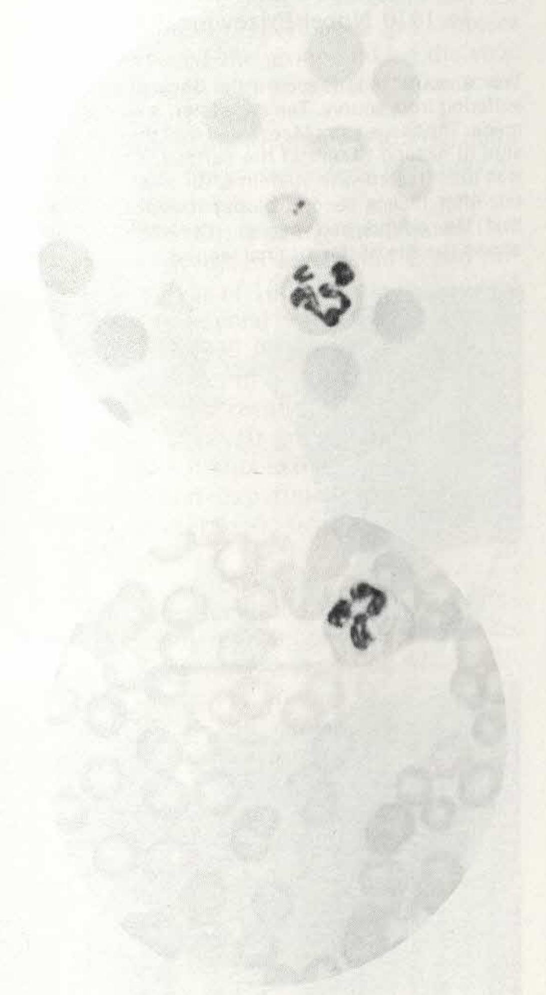
FOLIC ACID

Folic acid, or pteroylglutamic acid, ($C_{19}H_{19}N_7O_6$) received its name because it was first detected in leafy vegetables. (The Latin word for "leaf" is *folium.*) Folic acid is found not only in leafy vegetables but also in mushrooms, yeast, liver, kidneys and fresh fruits.

Folic-acid deficiency in people results in the failure of bone-marrow elements to form mature red blood cells, bringing about a variety of anemias. The vitamin is so widely distributed in foods that even a restricted diet generally supplies an adequate amount. A serious deficiency may occur, however, as a result of diseases of the digestive system. The body may not be able to utilize properly the folic acid derived from the diet.

Top: red-blood cells showing anemia due to folic acid deficiency. The cells are fewer in number and larger than would normally be the case. They are also irregular in shape. The mottled cell is a leukocyte. Bottom: after treatment with folic acid, the blood cells have become normal in size and shape and are now much more numerous.

Carl V. Moore



The daily requirement of folic acid is about 50 micrograms for the average adult. The vitamin is given to undernourished patients suffering from severe diseases, burns, radiation injury, or fractures. Folic acid is also used in the treatment of various anemias. It is particularly effective in the prevention and cure of sprue, a tropical deficiency disease, whose symptoms are anemia and acute diarrhea. Folic acid must be supplemented with vitamin B_{12} whenever pernicious anemia is present or suspected.

VITAMIN B_{12}

Until the 1920s, one of the most dreaded of all diseases was pernicious anemia. This malady, which is caused by a decreased rate of formation of red blood cells in the bone marrow, was invariably fatal. Patients seldom lived more than three years after the first symptoms set in. In the year 1926, George R. Minot and William P. Murphy of the Harvard Medical School brought about a revolution in the treatment of pernicious anemia by putting sufferers from the disease on a liver diet. Apparently this food contained some unknown factor that helped bring about the normal formation of red blood cells. Those suffering from pernicious anemia could now look forward to a normal span of life if they followed the liver diet thus prescribed.

It was not until 1948 that U.S. and British scientists succeeded in isolating the anti-pernicious-anemia factor. It turned out to be a compound of cobalt. It was given the name of vitamin B_{12}, or cyanocobalamin. It proved to have a most extraordinary effect in promoting the formation of normal red cells. An injection of a millionth of a gram a day was enough to keep a pernicious-anemia sufferer in good health.

The vitamin B_{12} empirical formula is $C_{63}H_{90}CoN_{14}O_{14}P$. The exact molecular formula was verified by X-ray crystallography by the British chemist Dorothy C. Hodgkin, in 1955. This outstanding work helped to bring her the Nobel Prize in Chemistry, awarded to her in 1964.

Norman Jolliffe, Norman C. Wetzel, and others have shown in studies with children that vitamin B_{12} may be effective in promoting growth in children on diets low in animal-protein factor.

The RDA of vitamin B_{12} is now set at three micrograms (0.003 mg). Normal persons absorb enough B_{12} from their diets through their intestinal walls. In the treatment of pernicious anemia, the minimum dose is one-millionth of a gram given daily by injection. Larger doses are given every three to six weeks. Liver, meat, eggs, and milk are prime sources of B_{12}.

Liver, meat, eggs, and milk are prime sources of $B_{12.}$

VITAMIN C (ASCORBIC ACID)

Albert Szent-Gyorgyi received a Nobel Prize in 1937 for the discovery of vitamin C ($C_6H_8O_6$). He described this sugar-like vitamin as making the body work better so that it is stronger and healthier. It plays an important part in the formation of connective tissue, bone tissue, and dentine. The vitamin is stored in the adrenal gland, pituitary gland, kidney, liver, ovary, eye, and other organs. It is released during heavy exercise and intense strain.

As we have already pointed out, vitamin-C deficiency results in scurvy. There is swelling and tenderness of the joints, swelling of the gums, loosening of the teeth, hemorrhages of the skin and mucous membranes, edema, and extreme skin sensitivity. It is believed that vitamin-C deficiency accounts for certain types of anemia that occur in infancy and in pregnancy.

Vitamin C is found very generally in both the plant and animal kingdoms. Citrus fruits, berries, green vegetables, cabbages, and green peppers are good sources of the vitamin. Potatoes, carrots, apples, and bananas contain less of it, but provide an adequate amount if eaten in sufficient quantities. People, monkeys, guinea pigs, and certain bacteria are the only living things that must obtain vitamin C from external sources. The other animals and plants synthesize the vitamin in their own bodies.

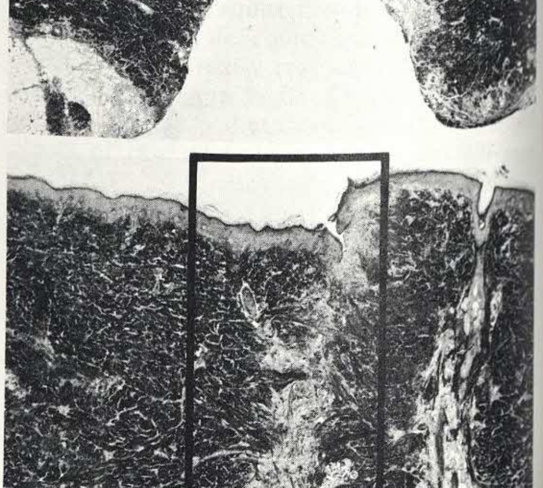
The daily need for vitamin C is from 30 to 80 milligrams. It is especially important that infants, pregnant and nursing women, and older people should have plenty of this important vitamin in their diet. Bland diets, used in treating various diseases the intestinal tract, are usually low in vitamin C.

Unless there is adequate refrigeration, much of the vitamin-C content of fruits and vegetables is lost in storage. Prolonged cooking produces the same effect. In order to be sure of obtaining our full quota of vitamin C, we should eat plenty of fresh fruits and vegetables. In the cooking and canning process, much of the vitamin-C content may be kept by excluding oxygen from the food by using a pressure cooker.

In 1970 Nobel Prizewinner Dr. Linus

Top: a wound was made on the back of a person suffering from scurvy. Ten days later, a biopsy was made. The tissue sample revealed that there was no sign of healing except at the surface. The person was then treated with vitamin C for a ten-day period. After that, a second biopsy (bottom) showed that the wound had healed. The middle panel shows the site of the original wound.

John H. Crandon



Pauling wrote *Vitamin C and the Common Cold,* in which he recommended taking 1,000 milligrams of vitamin C daily to prevent colds. He said that one gram daily would reduce the frequency of colds by 45 percent and reduce the total days of illness by 60 percent.

The rationale for the use of the vitamin seems to depend on a relationship between white blood cells and vitamin C. During a cold there is less of the vitamin in the white cells. Vitamin C is also believed to activate the immunizing system against viral infection.

Since Dr. Pauling announced his theory, there have been several experimental studies designed to test the theory. In three controlled studies, for example, Dr. Terrence W. Anderson of the University of Toronto's School of Hygiene could not verify Paulings findings. However, he did find the following:

- The average number of colds and the days of illness experienced per subject slightly favored the groups taking the vitamin -- but much less than the 45/60 percent predicted by Pauling.
- Dosage made no difference – 250 milligrams gave the same effect as 2,000 or 8,000 milligrams.

In 1976 Dr. Pauling announced that 10-gram daily doses of vitamin C had improved the lives of 100 patients in Scotland with cancers beyond conventional therapy. However, in 1979 Dr. Edward Creagan of the Mayo Clinic, in Rochester, Minnesota, announced the results of a comparable study. He gave 10 grams of the vitamin daily to 60 patients and a placebo to 63 in a double-blind experiment. His evidence showed no theraputic benefit of vitamin C.

VITAMIN D

The accessory food factor called vitamin D is really a group of several fat-soluble accessory food factors, of which the most important are vitamin D_2 (ergocalciferol: $C_{28}H_{44}O$) and vitamin D_3 (cholecalciferol: $C_{27}H_{44}O$). In the following paragraphs, it is understood that when we refer to vitamin D we have in mind the vitamin-D group.

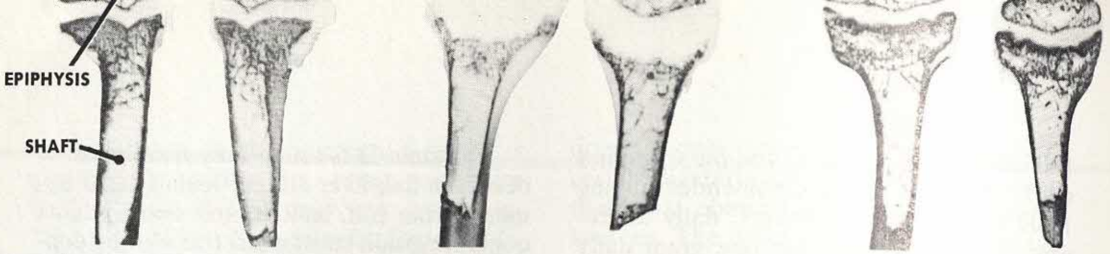
Vitamin D is found only in animals. It occurs in fish-liver oil, particularly that obtained from cod, halibut, and shark. Plants contain certain substances that can be converted into vitamin D by the action of ultraviolet light, either from sunshine or from artificial sources. These precursor plant substances are called *provitamins D*. The two most important ones are ergosterol, which yields vitamin D_2 when it is irradiated, and 7-dehydro-cholesterol, which yields vitamin D_3. Provitamins may be converted to vitamin D in two different ways. The dried plant material may be irradiated with ultraviolet light before it is taken into the body, or it may first be eaten and then converted to vitamin D in the body by exposure to ultraviolet light.

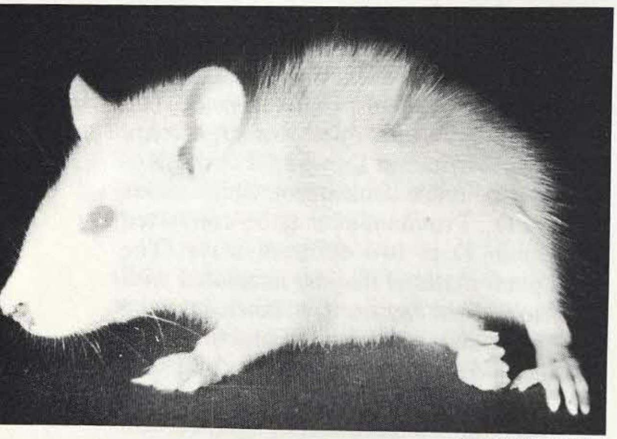
Vitamin D is primarily concerned with maintaining the proper balance of calcium and phosphorus in the body. Since the bones are composed largely of calcium phosphate, they are seriously affected if there is a vitamin-D deficiency. The result, in children, is the disease called *rickets*. The bones fail to harden. Therefore, when the long bones of the legs are subjected to the weight of the body, as when the child begins to walk, they become curved and the legs are bowed.

In rickets there is abnormal cartilage growth, resulting in enlarged joints. The teeth do not develop properly. The child is particularly likely to have dental cavities. The ribs become misshapen because of the pull of respiration upon the soft bones. The chest is deformed, causing the condition known as pigeon breast. The muscles are also affected, becoming flabby and weak. There may be thickening of the skull. Rickets may occur at any time during the growing period, but most cases develop before the age of two.

In adults, lack of vitamin D causes calcium phosphate to be withdrawn from the bones, making them more porous. This bone disease is known as *osteomalacia* ("bone softness," in Greek).

The normal daily allowance of vitamin D for infants and children and for pregnant and nursing women is 400 International Units daily. Other adults require only small




The Upjohn Laboratories

The mouse at the left has an advanced case of rickets. It has become so weak that it cannot stand up. Above are longitudinal, or lengthwise, sections of rat tibias. The tibia is one of two bones between the knee and the foot. The pair at the left are normal tibias. The middle pair are from a rat suffering from rickets. The gap between the epiphysis and the shaft is very wide, compared to the slight gap of the normal bones. The pair at the right show the results of treatment with cod-liver oil. The gap has been narrowed a great deal, but it will always be somewhat greater than normal.

amounts. The daily need can be met readily enough if the body is exposed to the ultraviolet rays of the sun for an adequate period of time, since these rays will transform the provitamins contained in the skin into vitamin D. For this reason, rickets almost never occurs in the tropics. It is found chiefly in the temperate zones, where radiation from the sun is markedly reduced, particularly in winter. Artificial ultraviolet light supplied by lamps may compensate, in part at least, for lack of sunlight.

If there is not enough irradiation with ultraviolet light, vitamin D may be obtained from the diet in the form of fish-liver oils. It can also be provided by activated sterols—that is, from the provitamins ergosterol or cholesterol, irradiated with ultraviolet light before they are taken into the body.

Adults are not so likely to have vitamin-D deficiency as children. Osteomalacia, the adult vitamin-D deficiency disease, is generally rare. It is found especially among those who stay indoors most of the time. Those who work in the fields or on boats do not suffer from the disease.

Vitamin D in excessive amounts can cause problems. The results of too much commercially prepared vitamin D (calciferol) results in demineralization of bone, increased concentration of calcium in the blood plasma, formation of kidney stones, and the deposition of calcium in soft tissues.

VITAMIN E

The name vitamin E is given to a group of closely related compounds called *tocopherols*. They are designated by letters of the Greek alphabet as alpha tocopherol ($C_{29}H_{50}O_2$), beta tocopherol, gamma tocopherol, and delta tocopherol. These substances belong to the fat-soluble groups of vitamins. They are found almost exclusively in plants: in nearly all green leaves and whole grains as well as in wheat-germ oil, peanut oil, and olive oil.

A biochemical and intrinsic role of vitamin E is unknown for animal cells. It has shown that lack of vitamin E leads to sterility in rats and to muscular dystrophy, or imperfect nutrition of the muscles, in guinea pigs. There is little evidence thus far of vitamin-E deficiency in humans.

Many studies have been made concerning the use of vitamin E in treating cardiovascular disorders. For example, some researchers have treated insufficient blood flow to the hands and feet with vitamin E, but the evidence is not conclusive. The vitamin may not be a peripheral dilator.

It is believed that normal adults need about 30 International Units of mixed tocopherals every day.

VITAMIN K

The Danish investigator Henrik Dam discovered in 1929 that if newly hatched chicks were placed on a fat-free diet, their blood did not coagulate readily and they developed hemorrhages in the skin, mucous membranes, and other parts of their bodies. Dam found that a fat-soluble vitamin obtained from green vegetables could prevent this condition. He called the substance vitamin K, from the first letter of the Danish word *koagulation*, meaning "coagulation."

This vitamin later came to be known as K_1 (phylloquinone: $C_{31}H_{46}O_2$). A U.S. biochemist, Edward A. Doisy, succeeded in isolating a related substance, which was called K_2 (farnoquinone). In 1943, Dam and Doisy received a joint Nobel Prize award for their contributions. A synthetic compound, called menadione, with vitamin-K activity, has now been developed.

Large amounts of vitamin K are found in alfalfa, spinach, carrot tops, soybean oil, tomatoes, rice bran, and casein. It is also manufactured by certain bacteria that are normally present in the intestinal tract.

This vitamin is essential for the formation, in the liver, of prothrombin, an important factor in blood clotting. Prothrombin, in the presence of various other substances, is converted into thrombin. Thrombin then acts upon the protein called fibrinogen to produce coagulation of the blood. People who have a vitamin-K deficiency have slow blood clotting. Therefore they are likely to suffer from hemorrhages. Normal adults rarely lack vitamin K, since the bacteria in their intestinal tracts can synthesize it.

Newborn infants are particularly liable to vitamin-K deficiency. The quantity of the vitamin derived from the mother before birth is small. At birth, the intestines do not contain the bacteria necessary to manufacture vitamin K. The ordinary diet during the first few days of life does not supply it. As a result, mild vitamin-K deficiency is the rule rather than the exception in the newborn. If their prothrombin falls to very low levels as a result of the deficiency, hemorrhages occur. The ill effects of vitamin-K deficiency in the newborn can be prevented in most cases by giving the vitamin to the expectant mother or to the infant at birth.

In the case of older children and adults, serious vitamin-K deficiency may develop if abnormal conditions within the body interfere with proper absorption of the vitamin. This takes place in the case of diseases such as obstructive jaundice, dysentery, sprue, and celiac disease. Other conditions, too, may bring about a deficiency in the blood-clotting vitamin. Mineral oil may dissolve vitamin K and cause it to be excreted with the feces. Certain drugs, such as the sulfonamides and the antibiotics, may destroy the bacteria that manufacture vitamin K in the intestine.

"MEGAVITAMIN" THERAPY

During the treatment of pellagra with niacin in 1937, researchers discovered that the mental disorders of the patients vanished along with the physical symptoms of the disease. By the early 1950's two Canadian physicians, Abram Hoffer and Humphrey Osmond were treating schizophrenic patients with high doses of niacin. In 1962 they reported that a long-term, controlled experiment with 82 patients showed that "megadoses" of niacin had relieved the symptoms of schizophrenia.

Thus began the "megavitamin" therapy of mental disorders. And out of this approach has grown the concept of orthomolecular psychiatry. (In Greek *ortho* means "right".) Orthomolecular means the right molecules to end the chemical imbalance causing the observed mental disorder.

There are many critics of this approach. In general, regular psychiatrists do not agree with orthmolecular therapists. They insist that the latter have not conducted controlled studies, since the time that Hoffer and Humphrey did their initial work on the subject.

DO YOU NEED SUPPLEMENTS?

All the vitamins essential to people's good health are found in a normal diet containing fresh vegetables and fruits, eggs, milk, fish, beans, and some unprocessed (natural) foods such as whole-wheat breads, cereals, and rice. However, many people do not eat balanced diets, so manufacturers have made vitamins available in "enriched foods." These synthetically prepared vitamins are just as useful to the body as the naturally occurring vitamins.

In shopping for food, it is essential to select a well-balanced diet that includes carbohydrates and fat. Milk provides the carbohydrate called lactose—milk sugar—along with other diet needs of young children, but some older people find milk and milk products difficult or impossible to digest.

Esaias Baitel, Rapho/PR

A PRIMER OF CARBOHYDRATES, FATS, AND MINERALS

By G. Edward Damon

We all need good nutrition. An understanding of what nutrients do in the body is important for anyone who wants to plan a well-balanced diet to meet this need.

Two essential nutrients in any diet are carbohydrates and fat. Here is how they work in your body to provide needed nourishment and keep you in good health. You will also read a few significant new things that have been learned about these nutrients in recent years.

CARBOHYDRATES

All carbohydrates are made of the chemical elements carbon, hydrogen, and oxygen. The hydrogen and oxygen are always in the same proportion as in water—H_2O. The name itself indicates the combination: carbo (carbon) hydrate (water).

The carbohydrates which provide nourishment in our foods are the various starches and sugars. The simple sugars—glucose, fructose, and galactose—are the foundation of most common carbohydrates. The disaccharides or double sugars—sucrose, maltose, and lactose—contain two simple sugars. Complex carbohydrates (polysaccharides) such as starch are formed by the union of many simple sugars.

All carbohydrates must be broken down by digestion into simple sugars before the body can use them. Some complex carbohydrates—for example, cellulose—cannot be digested by man. But they supply roughage needed for proper elimination of solid wastes from the body.

In a very real sense, all animals rely on plants for life. Plants containing chlorophyll (a green pigment) use the energy from the sun to make carbohydrates from the carbon dioxide in the air and from water. Humans and other animals eat plants, or animals which subsist on plants.

The major function of carbohydrates in the diet is to provide energy for the work of the body. They also allow the body to manufacture some B-complex vitamins. And they form part of the structure of many biological compounds. In addition, carbohydrates add flavor to our food.

FAO Photo by F. Botts

Crushing cassava in West Africa. Also known as the tapioca plant, cassava is a major source of starch in the world's tropical regions.

SOURCES OF CARBOHYDRATES

Carbohydrates are economical to produce in abundance. This characteristic helps a majority of the people in the world to survive. In the United States and Canada, carbohydrates provide 40 to 50 per cent of the total food energy. The entire population of the world obtains about 70 per cent of its energy from carbohydrates. The major world carbohydrate sources are the cereal grains, such as wheat, rice, corn, and oats; potatoes, many fruits and vegetables; peas; beans; taro; cassava (tapioca); and sugar cane and sugar beets. Many processed foods are rich in carbohydrates, including breads and other baked goods, jams and jellies, molasses, noodles, spaghetti, and dried fruits.

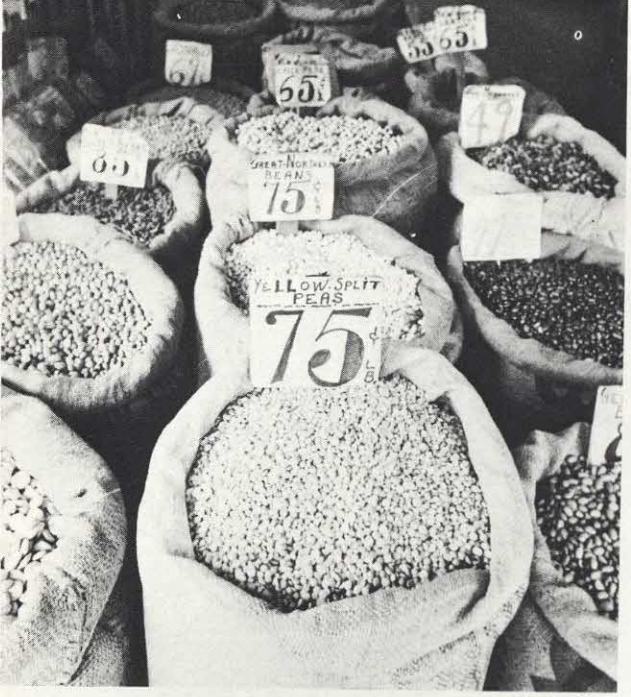
STARCH

Starch is the most important carbohydrate food source. Because it is the form in which plants store energy for future use, including the nourishment of embryo plants, the seeds of some plants are the richest sources of starch. These plants include the cereal grains, legumes, and the roots or tubers such as potatoes. The main constituent of cereals is starch, but important vitamins and minerals are also present in the outer layer and germ of the grain or kernel. Refinement, as in the milling of white flour, removes much of this outer layer and the germ. Enrichment of white bread and flour restores three of the B vitamins that are lost in processing, and it adds iron.

Most starchy foods are not very flavorful if eaten raw. Cooking swells the starch granules, breaks them open, makes them

Rice threshing in the Philippines. In Asia, rice is a leading cereal crop and, therefore, a leading source of carbohydrates.

United Nations photo by Yutaka Nagata



Jan Lukas, Rapho/PR

Leguminous plants such as the many varieties of peas and beans are rich in carbohydrates.

taste better, and allows them to be more easily digested. In some vegetables, such as immature corn and peas, a sweet taste is present. This disappears as the plant ripens and the sugar content changes to starch, which has little flavor. In some fruit, such as bananas, the unripened fruit contains starch that changes to sugar on ripening.

GLUCOSE, SUCROSE, and LACTOSE

Through digestion, the body changes the starch in foods to glucose. This sugar can be used as a source of energy by all the tissues in the body. If the body receives more glucose than it can use as energy, small amounts can be stored as glycogen – sometimes called animal starch – in the liver and muscle tissues. However, carbohydrates consumed in excess of the energy needs of the body are rapidly converted to fat. Hence, one can become overweight by eating excess calories in the form of carbohydrates. This is true of all excess calories, however. Carbohydrates are no more fattening than protein or fat.

Sucrose – common table sugar – is mostly produced from sugar cane and sugar beets. The sugars from the two sources are identical chemically. Refined sugar is an unusual food in that it is pure carbohydrate. Therefore, it is a source of calories only. It contains no vitamins, minerals, protein, or fat. Almost all other food sources contain some essential nutrients.

In the United States, the average individual consumption of sugar at present is over 45 kilograms per year. This is a substantial increase over the consumption prior to the twentieth century. The increase is related to the increased consumption of soft drinks, cakes and other bakery products, candies, syrup, jams and jellies, and other sweet manufactured products. Many of these foods contribute calories without providing much in nutrients. These calorie-rich foods should not be eaten at the expense of foods that provide essential vitamins, minerals, and protein. It should also be remembered that an excess of calories from any source leads to overweight.

Lactose, or milk sugar, is produced by mammals. It is an energy source for the young and a good source of high-quality protein, calcium, riboflavin, and vitamin A. The enzyme lactase must be present in order to digest lactose. Some people are deficient or lacking in this enzyme after early childhood. These people may find it difficult, or be unable, to digest milk or milk products containing lactose.

FATS

People have differing reactions to the word "fat." Many think of fat in terms of being overweight. A nutritionist would be more likely to think about the fat content of foods, and the basic composition of fats.

Fats are composed essentially of fatty acids and glycerol. Each fatty acid is made up of carbon atoms joined like links on a chain. The chains vary in length, with most edible fats containing four to 20 carbons.

Each carbon atom has hydrogen atoms attached as the charms might be on a charm bracelet. When each carbon atom in the chain has attached to it as many hydrogen atoms as it can hold (two), it is called a *saturated* fatty acid. When a hydrogen atom is missing from two neighboring carbons, a double bond forms between the carbon atoms, and the fatty acid is called *unsaturated.* A fatty acid which contains more than one such double bond in the chain is called *polyunsaturated*. The polyunsaturated fatty acid called linoleic acid is of particular nutritional importance. The body cannot manufacture it. Hence it is an "essential" fatty acid, because it must be supplied in the food.

Unsaturated fatty acids, and fatty acids composed of shorter chains, have lower melting points, and are liquids (oils) at room temperature. All food fats contain a mixture of saturated and unsaturated fatty acids. But in general, animal fats are more saturated than the liquid vegetable oils.

A rough division can be made in the degree of saturation between fats of animal and vegetable origin. However, there is some variation in saturation within each group, based on the sources. Other characteristics also vary. For example, coconut oil is highly saturated, but it is liquid because it has short carbon chains. Chocolate has a higher percentage of saturated fatty acids than most other vegetable oils.

Safflower, corn, cottonseed, peanut, and soybean oils are especially rich in linoleic acid. The labels on products made from these oils often state "high in polyunsaturates," or "high in polyunsaturated fatty acids." When oils have hydrogen added (hydrogenation), they become more solid. Margerine is an example of a food in which vegetable oils are hydrogenated to the consistency of a fat. In the process, the vegetable oil necessarily becomes more saturated.

FUNCTIONS OF FAT

Some fat is essential in the diet to provide linoleic acid, which is necessary for proper growth and a healthy skin. However, only a small amount of linoleic acid is required to meet this need: about 1 to 2 per cent of the total calories. Fats also carry fat-soluble vitamins into the body and aid in their absorption. In addition, fats serve as a concentrated source of energy. Because they slow digestion and stomach emptying, they delay the onset of hunger. Fats also contribute to our enjoyment of foods: they add flavor and improve the texture.

Fats are called a concentrated source of energy. They have an energy value more than twice that of carbohydrates or proteins. That is, 1 gram of fat provides 9 calories, while 1 gram of protein or carbohydrate provides only 4 calories.

This means that foods rich in fats add much to the caloric content of the diet. All calories in excess of body needs lead to fat deposits in the body. Some fat in the tissues helps to cushion body organs and to prevent heat loss. Too much fat deposited leads to being overweight.

A reduction in fat-rich foods is a sensible way to limit calories in the diet for reducing or controlling weight. In judging the amount of fat in one's diet, it is very easy to underestimate the total. Most people think only about visible fats: butter, margarine, lard, and cooking and salad oils. But much of the fat in the diet comes from less visible sources. Such sources include the fat particles and streaks in meat from wellfed animals; the fat in nuts, meats, and poultry; the fat added in some cooking; and the fat contained in many processed foods.

Per cent Fat	Food
90–100	Salad and cooking oils and fats, lard
80–90	Butter, margarine
70–80	Mayonnaise, pecans, macadamia nuts
50–70	Walnuts, dried unsweetened coconut meat, almonds, bacon, baking chocolate
30–50	Broiled choice T-bone and porterhouse steaks, spareribs, broiled pork chop, goose, cheddar and cream cheeses, potato chips, chocolate candy
20–30	Choice beef pot roast, broiled lamb chop; frankfurters, ground beef, chocolate chip cookies
10–20	Broiled choice round steak, broiled veal chop, roast turkey, eggs, avocado, olives, chocolate cake with icing, frenchfried potatoes, ice cream, apple pie
1–10	Pork and beans, many broiled fish, broiled chicken, crabmeat, cottage cheese, beef liver, milk, creamed soups, sherbert, most breakfast cereals
Less than 1	Baked potato, most vegetables and fruits, egg whites, chicken, consomme

CHOLESTEROL AND HEART DISEASE

The amount of fat in the human diet varies greatly in different parts of the world. In some densely populated or underdeveloped areas, the land must be used to produce the less expensive high carbohydrate foods such as grains. In such areas, fat provides as little as 10 per cent of the calories. In wealthier societies, where more animal products are consumed, fat may provide almost half of the calories. Fat now provides about 42 per cent of the calories in the U.S. diet, an increase of about 10 per cent over earlier this century. Many physicians and nutritionists believe that a lower fat intake would be desirable.

In recent years, people have read or heard much discussion about the amount of fat they eat. They also hear about the kind of fat they eat—saturated versus unsaturated or polyunsaturated. Most of the controversy involves the relationship of dietary fats and cholesterol to atherosclerosis. Cholesterol is a fat-soluble substance which is contained in foods of animal origin. It is also manufactured by nearly all body tissues. Atherosclerosis is a disease in which cholesterol and other fatty substances are deposited on the inner walls of arteries.

A high level of blood cholesterol has been identified as one of several risk factors in this disease. Some evidence has indicated that saturated fats in the diet tend to cause an increase in the levels, while polyunsaturated fats tend to result in decreased levels. Some medical authorities believe that many people would benefit from reducing their total consumption of fat, and from substituting moderate amounts of polyunsaturated vegetable fat for some of the saturated fats in their diets.

MINERALS

Just the right amounts of minerals in our diets is necessary, essential for good health and for growth. Tamper with the supply, and we find ourselves with varying types of deficiency diseases.

Minerals have two general body functions—building and regulating. Their building functions affect the skeleton and all soft tissues. Their regulating functions include a wide variety of functions, such as heartbeat, blood clotting, maintenance of internal body-fluid pressure, nerve responses, and transport of oxygen to body tissues.

Some minerals are needed in relatively large amounts in the diet—calcium, phosphorus, sodium, chlorine, potassium, magnesium, and sulfur. These minerals are classified as *macrominerals.* By Large amounts is meant more than 100 milligrams a day.

Other minerals, called *trace minerals,* or *trace elements,* are needed in smaller amounts. These are iron, manganese, copper, iodine, zinc, cobalt, fluorine, and perhaps others.

MACROMINERALS

Calcium is present in the body in greater amounts than any other mineral. There is about one kilogram or slightly more, in the body, almost all of which is concentrated in the bones and teeth. Small amounts of calcium help to regulate certain body processes such as the nerve function, muscle tone and irritability, and blood clotting. Although children and pregnant and lactating women have the highest calcium needs, all people need calcium in their diets. Milk and milk products are good sources of calcium. Other sources are green leafy vegetables (except spinach and chard), citrus fruits, and dried peas and beans.

Phosphorus is present with calcium, in almost equal amounts, in the bones and teeth, and is an important part of every tissue in the body. It is widely distributed in foods. Good sources are meat, poultry, fish, eggs, and wholegrain foods.

Sodium and chlorine are the two elements which combine to form table salt, but each has separate functions in the body. Sodium is found mainly in blood plasma and in the fluids outside the body cells, helping to maintain normal water balance inside and outside the cells. Sodium-rich foods include meat, fish, poultry, eggs, and milk. Many processed foods, such as ham, bacon, bread, and crackers, have a high sodium content because salt or sodium compounds are added in processing.

Chlorine is part of hydrochloric acid, which is found in quite high concentration in the gastric juice and is very important in food digestion in the stomach.

The daily U.S. diet and that of many other countries provides a high intake of sodium, much of it added to food as salt.

Many authorities believe the intake is much higher than desirable and that too much sodium leads to retention of water in the system (edema), which is typically associated with diseases such as high blood pressure, kidney disease, and congestive heart disease. Under conditions of heavy sweat losses or vomiting, salt intake may need to be increased, but the usual diet provides more than enough to cover losses from normal activities.

Potassium is found mainly in the fluid inside the individual body cells. With sodium, it helps to regulate body fluid balance and volume. A potassium deficiency is very uncommon in healthy people but may result from prolonged diarrhea or from diuretics (which cause high urine volume). It may also occur in children with extremely inadequate protein diets.

Magnesium is found in all body tissues, but principally in the bones. It is an essential part of many enzyme systems responsible for energy conversions in the body. A deficiency of magnesium in healthy humans eating a variety of foods is uncommon, but it has been observed in some postsurgical patients, and in alcoholics.

Sulfur is also present in all body tissues and is essential to life although its function has not yet been determined. It is a component of protein and a part of two vitamins, thiamine and biotin.

TRACE ELEMENTS

Most of the trace elements are bound to organic compounds on which they depend for transport, storage, and function.

Iron is an important part of compounds necessary for transporting oxygen to the cells and making use of the oxygen when it arrives. It is widely distributed in the body, mostly in the blood, with relatively large amounts in the liver, spleen, and bone marrow.

The only way a significant amount of iron can leave the body is through a loss of blood. Women of childbearing age, pregnant women, and growing children are most likely to suffer from iron-deficiency anemia because they have higher needs for the mineral.

Only a few foods contain iron in useful amounts. Liver is an excellent source. Other sources are meat products, egg yolk, fish, green leafy vegetables, peas, beans, dried fruits, whole-grain cereals, and iron-enriched cereal products.

Manganese is needed for normal tendon and bone structure and is part of some enzymes. It is abundant in many foods, especially bran, coffee, tea, nuts, and peas.

Copper is involved in the storage and release of iron to form hemoglobin for red blood cells. The need for copper is particularly important in the early months of life and, if the intake of the mother is sufficient, infants are born with a store of copper. Copper occurs in most unprocessed foods. Organ meats, shellfish, nuts, and dried legumes are rich sources.

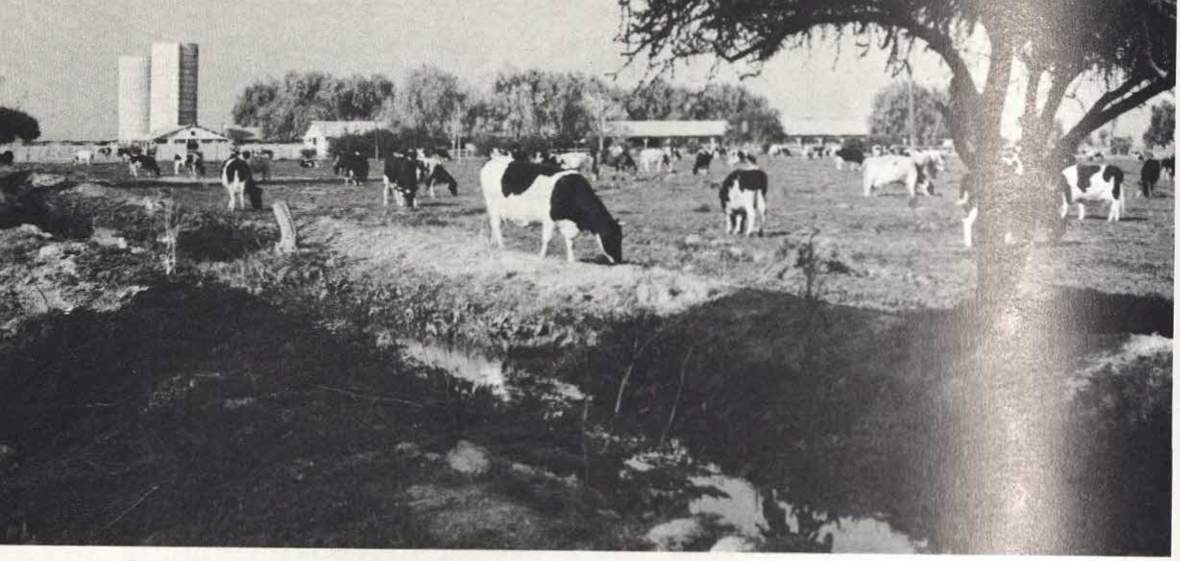
Iodine is required in extremely small amounts, but the normal functioning of the thyroid gland depends on an adequate supply. With a deficiency of dietary iodine, thyroid enlargement (goiter) occurs. Sea foods are the richest sources.

Zinc is an important part of the enzymes that, among other functions, move carbon dioxide, via red blood cells, from the tissues to the lungs where it can be exhaled. Recent studies indicate that zinc deficiency may be involved in the loss of the sense of taste and in delayed wound healing. Zinc is usually associated with the protein foods. Good sources are meats, fish, egg yolks, and milk.

Cobalt by itself is not essential in the body, but it is a part of vitamin B_{12} which is an essential nutrient. Strict vegetarians can become vitamin B_{12} deficient because it occurs only in trace amounts in plants.

Chromium, acting with insulin, is required for glucose utilization. A deficiency can produce a diabetes-like condition. Good sources are dried brewer's yeast, whole-grain cereals, and liver.

Fluorine, like iodine, is found in small and varying amounts in water, soil, plants, and animals. Fluorine contributes to solid tooth formation and results in a decrease of dental caries, especially in children. There is also evidence that fluorine helps retain calcium in the bones of older people.



Dairy farms, such as this one in Chile, are sources of high-quality protein.

United Nations

A PRIMER OF PROTEINS AND FIBER

by G. Edward Damon

WE all need good nutrition. In order to obtain a well-balanced diet, we should understand what nutrients do in the body. Proteins are among the essential nutrients, and fiber is also an important part of our diet. Here are the basic facts about them.

WHAT ARE PROTEINS?

To the average person, "protein" means "meat." Some would include fish and poultry, and some might add eggs and milk. Thus, most people associate protein with animal products. Lately, however, vegetable proteins have been widely advertised and sold in supermarkets as meat extenders or meat substitutes. Thus more people are becoming aware that there are both plant and animal proteins.

Proteins are, besides water, the most abundant substance in body cells, and they have almost endless functions in the body. They account for the tough, fibrous nature of hair, nails, and ligaments, and for the structure of muscles. They are a part of hemoglobin, which transports oxygen in the blood; of insulin, which regulates blood sugar; and of the enzymes necessary for digestion of food.

Amino acids—which contain nitrogen that is essential to animal life—are the building blocks of proteins. It is the variations in the composition and arrangement of amino acids in the protein molecule that give protein its remarkable versatility. In protein molecules, hundreds of amino acids are linked into long chains. About 20 amino acids are commonly found in proteins. This makes possible an almost infinite number of combinations and sequences in the amino acid chains. An almost infinite variety of proteins is found in plant and animal tissues.

FUNCTIONS OF PROTEINS

Proteins (actually amino acids) are required by the body for building and maintaining body tissues. They are an important part of protoplasm, the living material of the cell, and are found in association with the cell's genetic material. The greatest amounts of protein are needed when the body is building new tissue rapidly, such as during infancy, pregnancy, or when a mother is nursing a child. Extra protein also is needed when excess destruction or loss of body protein occurs from hemorrhage,

FAO photo by R. Coral

United Nations

Proteins from fish and poultry provide a good balance of amino acids for humans and animals. Right: fish market in Dacca, Bangladesh. Above: fish meal shipped from Peru for livestock.

burns, surgery, infections, or other causes. Contrary to popular belief, people engaged in sports and other strenuous activities do not need increased protein (except for the small amount of protein needed for developing muscles during conditioning), provided their diets supply enough calories from carbohydrates and fats.

Proteins are needed for building the thousands of enzymes which control the speed of chemical reactions in the body. They are also needed for making hormones such as insulin and thyroxine, which regulate metabolism. Metabolism is a term for the chemical processes occurring in the body. In addition, proteins are needed for forming antibodies which combine with foreign proteins that enter the body, producing an immunity response that helps ward off harmful infections. They also help regulate the water balance and the acid-base balance in the body.

Proteins, like carbohydrates and fats, can be burned to supply energy. Therefore, when the diet does not supply enough calories from those other two nutrients, proteins are used for energy, even at the expense of building body protein. Some protein is needed regularly in the diet because the body has little protein reserve. If more protein is eaten than is required for the nitrogen needs of the body, the extra protein is used for calories or is converted to body fat. Thus, you can become "fat" from eating excess calories in the form of protein just as much as from too many calories from carbohydrates or fats.

Most Americans today eat more protein than their bodies need. This excess protein consumption is economically wasteful, because foods that provide primarily carbohydrates and fats are cheaper sources of calories. It is also biologically wasteful, because only part of the protein molecule can be used for energy. The amino groups cannot be so used and instead must be split off and excreted by the kidneys.

ESSENTIAL AMINO ACIDS

To be used in the body, protein in food must be broken down by digestion to amino acids and absorbed into the blood. The body uses the "pool" of amino acids available from foods and metabolism to build the body proteins it needs. The efficient building of body tissues requires a well-balanced mixture of amino acids. Some amino acids can be made by the human body, but several must be provided preformed from foods. The latter, therefore, are known as the "essential" amino acids.

The essential amino acids are required in different amounts by the human body. Food proteins providing all of the essential amino acids in the proportions needed by humans are called "complete" or high quality. A protein low in an essential amino acid is said to have a "limiting" amino acid because it limits growth. If the proportions of essential amino acids are too unbalanced,

FAO photo by F. Betts

Mung bean noodles. The bean is being used to combat protein malnutrition in the Far East.

the protein will not support either growth or maintenance. When combined, two proteins, each of which has a different limiting amino acid, may complement one another and provide total protein of high biological value.

Because animal body composition is similar to that of humans, animal products contain more nearly the balance of amino acids required by humans than do plant foods. Meat, fish, poultry, milk, cheese, and eggs are all sources of high quality protein. Vegatable proteins are usually low in one or more of the essential amino acids. Plants also have less protein in their tissues than do animals. Legumes (peas and beans) contain larger amounts and better quality protein than other plant sources.

Combinations of proteins from different vegetable sources (in a meal or in a food product) may complement one another and provide improved total protein quality. Legumes combined with many cereals are nutritious. For example, beans and rice combinations provide both a good quality and quantity of protein. Vegatable sources supplemented with some high quality protein, such as breakfast cereal with milk, or macaroni with cheese, also are nutritious combinations. By adding the essential amino acid which is low in a particular protein, such as methionine to soy protein, it is possible to prepare meat substitutes equal to animal products in terms of protein quality.

Vegetarians, who obtain their diets only from plant sources, need to select from a wide variety of plants to ensure that they are getting the amount and quality of protein they need. They also need to take vitamin B_{12} as a dietary supplement, because plant foods contain only traces of this vitamin. The inclusion of even small amounts of milk, cheese, and eggs makes it simpler to select a diet that is adequate in both quantity and quality of protein.

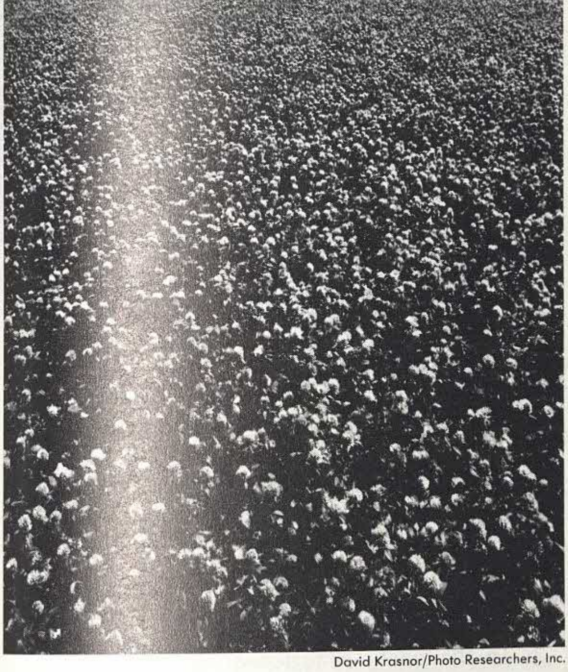
PROTEIN LABELING

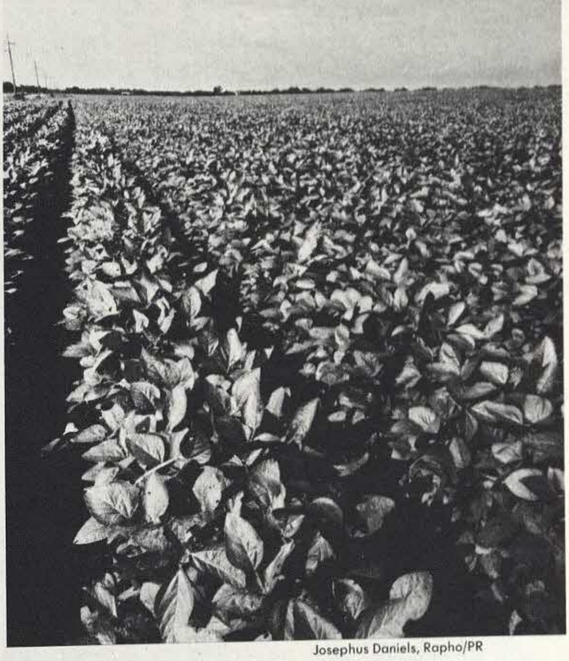
On nutrition labels, the grams of protein in a serving or portion of food are stated in the upper section of the nutrition information panel. The percentage of the U.S. Recommended Daily Allowance (U.S. RDA) of protein is given in the lower section. The U.S. RDA for protein is based on the protein quality of foods. In effect, food products which contain total protein that is of high biological quality can claim a higher percentage of the U.S. RDA on labels than foods which contain total protein of lower quality. This part of the regulation is intended to protect the consumer from deceptive labeling claims on products which contain large amounts of low quality protein.

Differences in protein quality in foods are typified by comparing products such as beef-and-vegetable stew and canned kidney beans. A one-cup serving of either would contain about the same amount of protein, but the stew would contribute a higher percentage toward the U.S. RDA for protein, because beef contains high quality protein. However, the beans are a good and fairly inexpensive source of protein. When combined with a small amount of cheese, egg, or other animal protein, they will provide protein equal in quality to the stew.

WHAT IS DIETARY FIBER?

The nutritional qualities of foods are usually described in terms of the foods' protein, carbohydrate, fat, vitamin, and mineral content. The importance of the fiber, or roughage, in foods is less frequently mentioned. However, the value of certain foods in promoting bowel regularity probably has been recognized through the ages.


David Krasnor/Photo Researchers, Inc.


Josephus Daniels, Rapho/PR

Legumes are major protein sources for humans and livestock. Left: clover serves as animal fodder and also improves soil fertility. Right: soybeans provide one of the best balances of amino acids of any vegetable protein.

The fiber in our diet comes only from plant sources and does not include the tough, or "fibrous," portions of some meats. It is composed of complex carbohydrates, such as cellulose, and other substances which constitute the cell walls and structural formations in plants. The fibrous sections of some foods—for example, the stems of salad greens, celery, wheat bran, and apple skins— contain large amounts of these materials.

This fiber from plants is important in the diet. It stimulates the normal action of the intestinal tract in removing waste products. In addition to providing bulk, the fiber absorbs many times its weight in water, thus helping to make the waste products softer. The greater bulk promotes regularity and more frequent elimination.

Many diets for weight reduction encourage the consumption of raw vegetables and fruits. This is often helpful, because these foods contain fair amounts of fiber and are generally low in calories. The increased bulk also contributes to a feeling of fullness that helps to satisfy the dieter.

Recent studies have suggested that dietary fiber may have an additional contribution to our well-being, probably as a result of the greater bulk and more rapid elimination. Some researchers feel that an adequate quantity of dietary fiber may protect against many noninfectious diseases of the large intestine. These conditions include cancer of the colon, hemorrhoids, appendicitis, colitis, and diverticulosis (pouches protruding from the intestinal wall). The incidence of these diseases appears to be lower in societies where the diets contain larger amounts of dietary fiber. Some researchers have also associated increased dietary fiber with reduced blood cholesterol levels. This suggests that a relationship may exist between dietary fiber and freedom from atherosclerosis (fatty deposits on the inner walls of arteries). Based on these research reports, some health authorities believe that an increase in dietary fiber would be beneficial for people who tend not to eat many vegetables and fruits.

CONSUMPTION OF FIBER

Little effort has been made to evaluate the consumption of dietary fiber. Until recently, there has been little interest in the value of fiber either as roughage or in

Bruce Roberts, Rapho/PR

Bruce Roberts, Rapho/PR

Fiber, or roughage, is needed for good body health. Major sources of fiber include fresh fruits and vegetables (left) and whole-grain cereals (right).

connection with disease. However, some foods which are major contributors to fiber—whole-grain flour and cereal, potatoes, and fresh fruits and vegetables—have been consumed less in recent years. The consumption of dried beans and peas, which are also good sources of fiber, has also decreased. Increased consumption of meat and poultry, which do not provide fiber, has also been responsible for a lower level of dietary fiber.

Why can't manufacturers just add fiber to the foods we normally eat? To a certain extent, it could be done. It would be easy to put more fiber in some breakfast cereals, but it wouldn't be acceptable in many other foods. Fiber, to be noticeably beneficial, would have to be in much larger amounts than introduced vitamins, which are added in milligram or microgram quantities. Fiber would have to be added in grams, and this would alter the appearance, taste, chewiness, and mouth-feel of many foods.

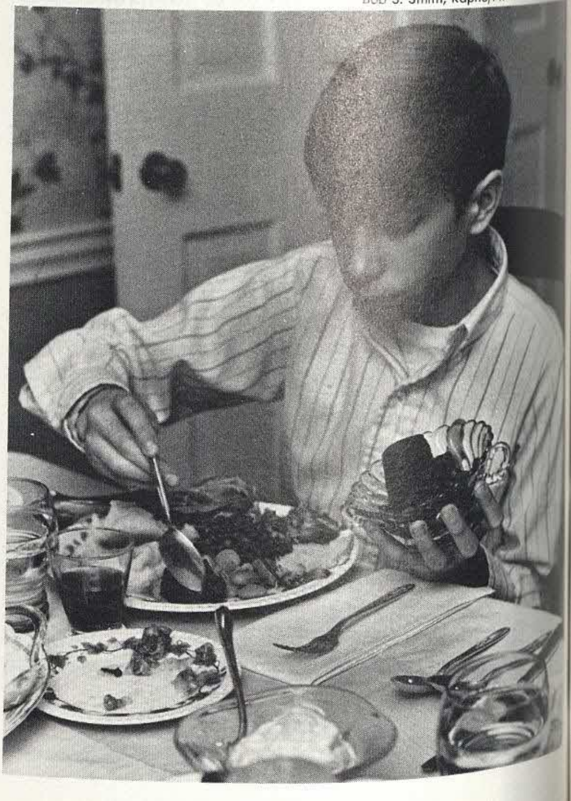
At any rate, it is possible to get enough fiber in regular foods by including some foods from a variety of plant sources every day. We need to keep in mind that dietary fiber is made up of many substances, and the composition differs in cereals, vegetables, fruits, and seeds. So a variety of plant foods is needed in our diets. This agrees with the advice often given by nutritionists: "For good nutrition, select your diet from a wide variety of foods."

As a general rule, unrefined foods contain more roughage than refined foods, because some fiber is usually removed in processing. For example, breads and breakfast cereals made from whole wheat contain more fiber than products made from wheat that has had the bran removed. Raw apples or other fruits contain some roughage, primarily in the skins, which is not present in processed products. Fruits with seeds, such as strawberries, raspberries, and figs, are high in fiber. Raw and cooked vegetables are excellent sources of fiber.

In the past, Americans haven't paid much attention to the roughage in their diets. Because of the increasingly recognized importance of roughage, however, the nutrition spotlight is beginning to focus on dietary fiber.

This article has discussed the functions of proteins and fiber in a well-balanced diet. To maintain good health, attention must also be payed to several other dietary constituents.

Bob S. Smith, Rapho/PR



EXERCISE AND REST

by Alan C. Burton

In one respect, at least, the human body is like the motor of an automobile. It is constantly transforming the chemical energy contained in its fuel—that is, the food it swallows—into heat energy and mechanical energy. The toast you eat for breakfast is burned in the body just as truly as gasoline is burned in the cylinders of an automobile. Part of the chemical energy supplied by the toast is changed into the heat energy that keeps your body warm. Another part of it goes into the mechanical energy that makes it possible for your muscles to pump blood through your body or to move your chest in breathing.

Even if you lie idly in bed all day, your body continues to transform a certain amount of the chemical energy provided by food into mechanical energy and heat energy. The heart keeps on pumping blood in the circulation. The diaphragm continues to contract and expand, thus drawing oxygen into the lungs and forcing carbon dioxide and water vapor from them. The movements of the intestines continue as food is digested and absorbed into the tissues. The body must be kept at its normal temperature so that activities such as those described above may be carried out as effectively as possible.

METABOLIC RATE

The rate at which your body transforms energy when it is at rest is called its *basal metabolic rate*. *Metabolism* refers to those processes that build up protoplasm, a basic cell ingredient, and those that break it down into simpler substances, with the accompanying release of energy. In the basal, or resting, state of the body, most of the chemical energy provided by food is changed into heat energy and only a little into mechanical energy, since most of the muscles are relaxed and inactive.

© 1978 Jim Anderson/Woodfin Camp

There is no age limit to exercise programs when they are properly designed for the individual.

The rate at which energy is transformed in the body increases greatly when you rise from your bed and go about your daily activities—moving the arms and fingers in the act of eating, or walking briskly to a bus, or playing a game of tennis. Even when you are simply standing still, the muscles that have to do with posture must exert themselves in order to hold the body upright.

The transforming of chemical energy into mechanical energy by the muscles is called *muscular exercise*. We generally think of exercise as the kind of activity that is involved in playing a game of golf, or running a race, or carrying the puck in a hockey game. Scientifically, however, the word exercise has a far broader meaning. It refers to any kind of muscular activity, violent or gentle, from lifting a heavy weight to threading a needle.

No engine is perfectly efficient, since a

Exercise classes for senior citizens are being set up all over the country.

John Keating

good deal of its chemical energy is transformed into heat energy instead of mechanical energy. In the case of the human body, only about one-quarter of the energy we obtain from food is changed into the energy required for breathing, talking, writing, and the like. The rest is changed into heat energy.

Rate of Energy Transformation by the Body in Different Kinds of Muscular Exercise

Type of Exercise	Rate in Mets*
Resting, or basal	1.0
Sleeping	0.8
Standing quietly	1.2
Dressing and undressing	1.4
Dishwashing	1.6
Slow walking 3 kilometers per hour	2
Cycling	3 to 7
Rowing	3 to 10
Fast walking 6-7 kilometers per hour	4
Mining coal	4
Sawing wood	5
Skiing	6 to 10
Running 9 kilometers per hour	7
Long-distance running	10 to 15
100-meter dash in 10 seconds	100

*A Met represents the resting, or basal, rate of energy transformation of an average person. The word comes from metabolism. It is about equal to the rate of energy used in a 100-watt electric bulb.

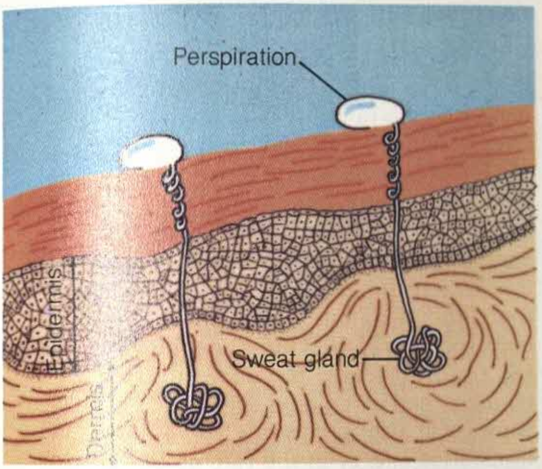
When the muscles become active, more chemical energy is required so that increased mechanical energy may be made available. The table shows the energy increases in different kinds of exercise.

The figures in this table are only roughly accurate, since the actual rate of energy transformation will depend on the strenuousness with which a given activity is carried out. The energy required to perform a task is much greater if it is done rapidly than if it is done slowly. Friction has to be overcome in the different muscles that are involved: the higher the speed of movement, the greater the forces of friction. This is true also of mechanisms like automobiles. You use up more gasoline when you drive your car a distance of 10 kilometers at 80 kilometers per hour than when you drive the same distance at 50 kilometers per hour.

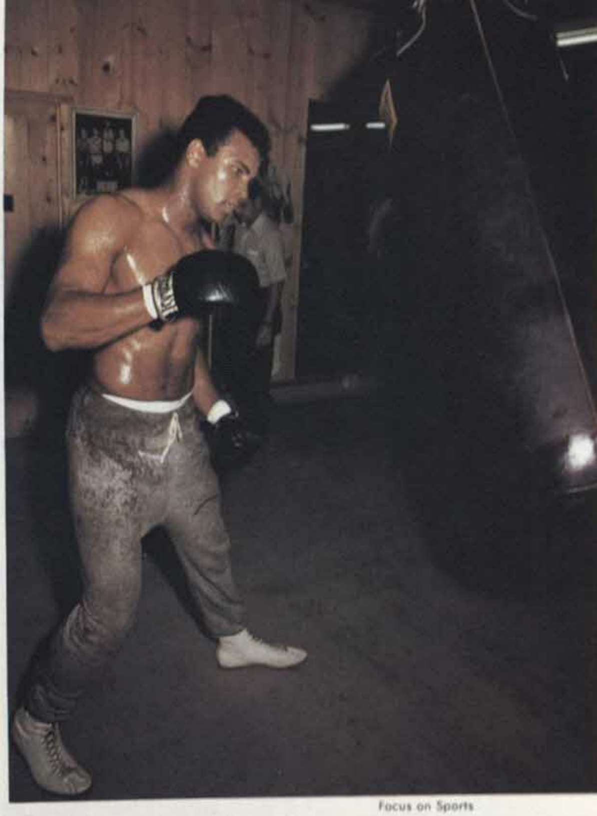
Naturally, more food will be required as the rate of energy transformation increases. A modest amount of food will suffice for an invalid resting quietly in bed all day long. A miner will have to eat much more if he is to do his job effectively. Athletes must also be well fed.

WHAT HAPPENS DURING EXERCISE?

Up to a certain point, one can compare what happens in the body during exercise with what happens when a driver steps on the accelerator of his car. The carburetor feeds more gasoline to the engine and the engine runs faster—that is, the chemical



When you exercise briskly, blood circulation increases near the surface of the body. The sweat glands (above) become active and the skin shows beads of perspiration. As sweat evaporates, it cools the body. Very strenuous exercise (right) still raises body temperature somewhat.



Focus on Sports

energy of the fuel is changed into heat energy and mechanical energy at an increased rate. But it is not enough to supply the engine with more gasoline. If that were all, your car would soon be on the scrap heap. A great many other factors are involved.

In order to burn the fuel, a greater supply of oxygen is needed. Hence, the carburetor now sucks in air to the engine in greater quantities than before. A good deal more heat is generated at high speeds. To keep the engine from becoming overheated, more cooling is now provided by the water pump, which circulates water through the engine jacket, and by the fan, which blows air over the radiator. The ignition now produces more sparks per minute to fire the fuel in the cylinders. More oil now flows in order to lubricate the working parts. Many operations are required, therefore, in order to bring about an increased rate of energy transformation in your automobile.

So it is with the human body when it passes from rest to exercise. The muscles must transform chemical energy into mechanical energy at a faster rate than before, but a good many other things must happen, too.

To burn more fuel, the muscles need a greater supply of oxygen that is carried to them by the circulation of the blood. Therefore, the flow of blood to the muscles must increase greatly. To charge the increased blood flow with sufficient oxygen, the lungs must pump more air. Notice that your breathing becomes deeper and faster the minute you start exercising.

As the muscles become more active, more chemical energy is transformed into heat energy. This extra heat would quickly raise the body temperature to fever if effective cooling were not provided.

The increased circulation of blood to the surface of the body—that is, the skin—helps to carry the heat away faster than normally. The sweat glands all over the body surface burst into activity and drench the body with perspiration. As the sweat evaporates, the body loses heat to its surroundings. These cooling devices are quite effective, but they do not suffice if a person engages in particularly strenuous activity. The body temperature of the most perfectly trained athlete is bound to rise if he or she runs a race, or plays several fast sets of tennis, or runs a few kilometers.

INCREASE IN OXYGEN SUPPLY REQUIRED

The human mechanisms that take part in exercise are linked up by the action of the nervous system, which governs the action and the cooperation of all the parts of the body in muscular exercise. We still do not fully understand just what is involved. For example, what brings about the increase in the oxygen supply that is required for muscular exertion? We know that the rate and depth of breathing are controlled by the amount of carbon dioxide in the blood, but this is by no means the whole story. Nerve impulses from the muscles to the brain undoubtedly play a part. It is probable, too, that when the motor cortex – the part of the brain that controls the activity of the muscles – goes into action, it sends nerve messages to the various muscles that control breathing.

In exercise, as we have seen, the supply of oxygen to the muscles increases as they become more and more active. There is a limit, however, to the rate at which the lungs can breathe air and the heart can pump blood. The maximum rate for each individual depends on his fitness and his training for a particular form of exercise.

OXYGEN DEBT

Professor Archibald V. Hill, of England, a Nobel Prize winner in physiology, measured the rate at which a group of athletes breathed in air and absorbed oxygen. He found that an athlete of average size, at rest, uses nearly one fourth of a liter of oxygen each minute. When doing violent exercise, he can take in roughly 15 times as much oxygen, or approximately three or four liters a minute. This quantity would correspond to 15 Met units. Yet how can we say that 15 Mets is the maximum rate for taking in and using oxygen, when the table shows that a sprinter in the 100 meter dash transforms energy at the rate of 100 Mets?

Here our comparison of the human body with the engine of an automobile breaks down. The car engine can only live on its income. By that we mean that it can burn only as much gasoline as the fuel pump supplies, together with as much oxygen as the carburetor can draw in. This, of course, sets a definite limit to the speed of a car. If it has a maximum speed of 240 kilometers per hour on a certain track, it cannot go faster than this, even for a very short time. The maximum speed for a two-kilometer race will be the same as for a 20-kilo-

Strenuous sports, such as tennis, require large expenditures of energy; they are good for building muscle tone and coordination.

Alpha

meter race: 240 kilometers per hour.

This is not true in the case of the human machine. The average speed of a sprinter in a 100-meter dash is not the same as that of a miler or a ten-mile runner, as world running records show. In a 100-meter dash, the average speed may be a little over 35 kilometers per hour; in a 440-meter run, nearly 32 kilometers per hour. In a 1,600-meter run, average speed is nearly 25 kilometers per hour.

For distances greater than 1,600 meters, average running speeds do not decrease markedly: down to about 19 kilometers per hour. The energy-change rate in long-distance runners is about 15 Mets.

Evidently, in the case of sprinters, the muscles can transform energy at a much greater rate than this. In other words, the muscles are not limited, as is the automobile engine, to living on income, but for a short time at least they can pile up an oxygen debt. That is, they can transform chemical energy into mechanical energy and heat energy without any reaction with oxygen. They can do this by breaking down the glycogen, or animal starch, stored up in the muscles and liver, to form lactic acid—a reaction that does not require oxygen.

Extra oxygen will have to be taken in later to pay back this oxygen debt when the heavy exercise is over. This extra oxygen will then react with the lactic acid that has accumulated in the muscles. Part of the lactic acid will be reconverted into glycogen, which will be stored anew in the muscles and liver. Part of it will yield carbon dioxide and water, which will be passed out of the body with other waste products.

The total oxygen debt that can be accumulated is strictly limited. It is about 14 liters of oxygen for a trained athlete. When he has piled up the maximum oxygen debt, the store of glycogen in his muscles has been practically used up and excessive quantities of lactic acid have accumulated. His muscles are now completely exhausted and his legs will buckle under him.

In the 100-meter dash, much of the energy comes from piling up an oxygen debt, since a good sprinter does not take a single breath from start to finish. In con-

Sam Boss/FPG

Running has become a popular sport, and is no longer a lonely one. Men and women of all ages now participate in long-distance marathons.

trast, in long-distance runs there is a more or less steady balance between the output of energy and the intake of oxygen. The runner accumulates an oxygen debt only in the final sprint for the tape. When a new record is established, it is often because the winner has found a better method – for him, that is – of spending both his income of oxygen and his borrowed oxygen, so that he arrives almost bankrupt at the tape.

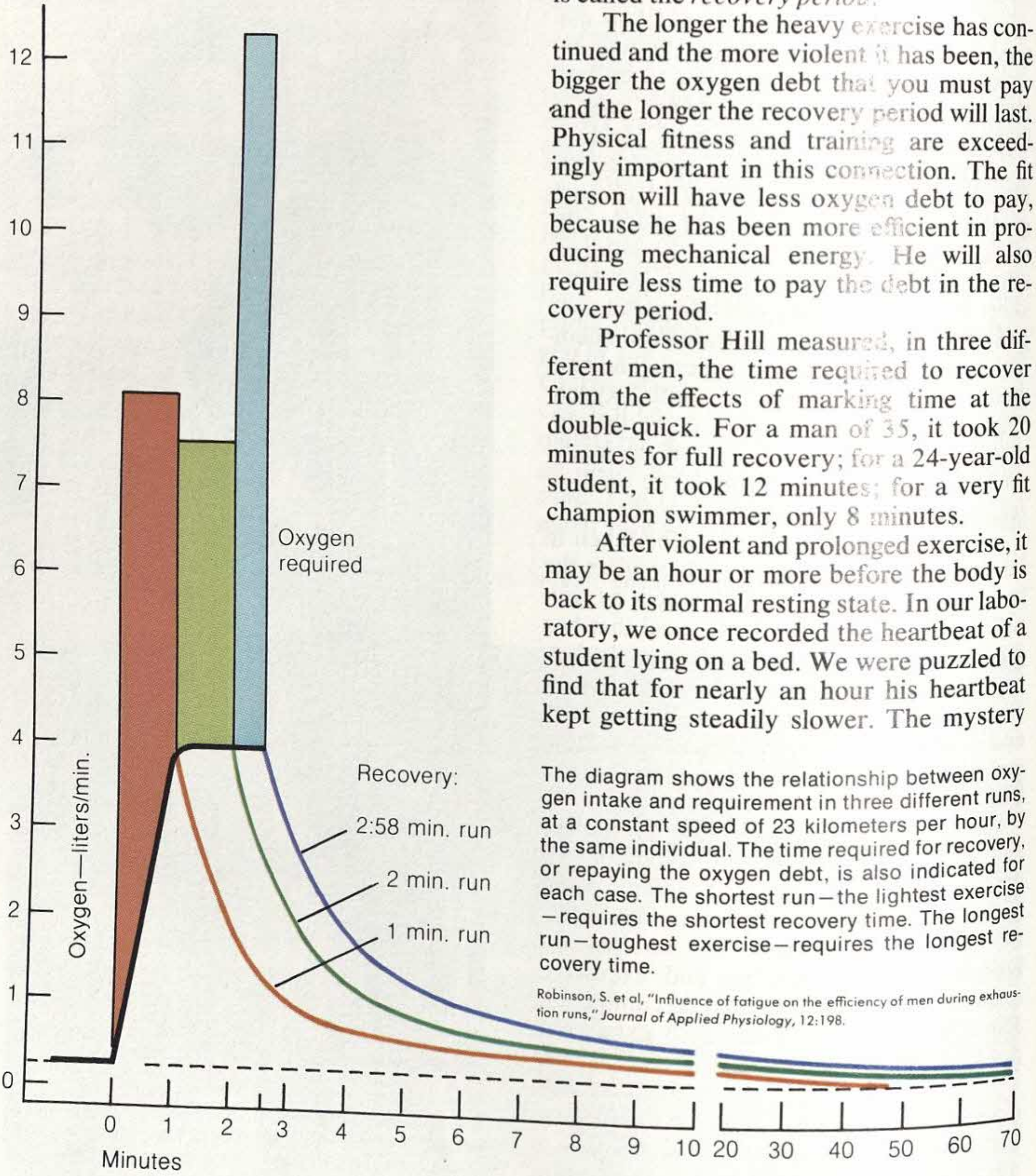
RECOVERY PERIOD

When you stop doing a violent exercise, your body does not return at once to its normal state. For quite a while, you will breathe fast and deeply, your heart will pound, and your skin will perspire. In fact, you will not feel up to par again until practically all the oxygen debt has been paid. The period during which this debt is made good is called the *recovery period*.

The longer the heavy exercise has continued and the more violent it has been, the bigger the oxygen debt that you must pay and the longer the recovery period will last. Physical fitness and training are exceedingly important in this connection. The fit person will have less oxygen debt to pay, because he has been more efficient in producing mechanical energy. He will also require less time to pay the debt in the recovery period.

Professor Hill measured, in three different men, the time required to recover from the effects of marking time at the double-quick. For a man of 35, it took 20 minutes for full recovery; for a 24-year-old student, it took 12 minutes; for a very fit champion swimmer, only 8 minutes.

After violent and prolonged exercise, it may be an hour or more before the body is back to its normal resting state. In our laboratory, we once recorded the heartbeat of a student lying on a bed. We were puzzled to find that for nearly an hour his heartbeat kept getting steadily slower. The mystery



The diagram shows the relationship between oxygen intake and requirement in three different runs, at a constant speed of 23 kilometers per hour, by the same individual. The time required for recovery, or repaying the oxygen debt, is also indicated for each case. The shortest run – the lightest exercise – requires the shortest recovery time. The longest run – toughest exercise – requires the longest recovery time.

Robinson, S. et al, "Influence of fatigue on the efficiency of men during exhaustion runs," *Journal of Applied Physiology*, 12:198.

Skiing, especially downhill racing, consumes six to ten times the energy needed to maintain the resting metabolic rate.

Clyde H. Smith/Alpha

was solved when we found that he had just played in a basketball game and that he was not very fit.

WATER DEBT

During the recovery period following heavy exercise, you will note that you become very thirsty. The body is serving notice in this way that it has lost a great deal of water in perspiration during the exercise and that this *water debt* must be made up. The total weight of water lost in this way may amount to several kilograms.

In long-continued heavy work, especially in hot surroundings, it is a good idea to drink not pure water but water with a little salt added. The reason is that, together with water, the body has lost a considerable amount of salt as a result of perspiring freely.

There does not seem to be any salt-craving sensation in the human body, corresponding to the water-craving sensation, or thirst. This deficiency is really most unfortunate, since it may cause trouble. For example, for many centuries miners used to suffer from severe cramps in the muscles. Then it was discovered that they simply needed salt to make up for the salt that they had lost in sweat. When salt was supplied, this ailment practically disappeared.

In very violent exercise, though the oxygen debt may be paid back in an hour or so, the muscles may not fully recover for days. The body may be stiff and sore, blisters may form, and there may be other distressing symptoms. All this indicates that the exercise in question is altogether too violent for the sufferer, at least in his present state of training.

EFFECT OF SLEEP

It has long been considered that the activity of the muscles and the brain and nervous system throughout the day results in the gradual accumulation, in the body, of chemicals that have something to do with tiredness, or fatigue. We do not know just what these chemicals are, although much research has been done trying to find them in the blood. The removal of these products of fatigue is probably very slow and not complete in the usual recovery period we have discussed. It is thought that only after a good night's sleep is the body really back to normal and ready for another day's exercise and work.

In sleep, the muscles are probably more relaxed than at any other time, except when the body is under the influence of a total anesthetic. The rate of metabolism is reduced up to 20 per cent below the basal, or resting, level. When we awake at last, renewed and refreshed, our muscles are ready for the stresses that the following day may impose upon them.

[illegible] de la [illegible]

Henri Rousseau's "The Sleeping Gypsy" describes a universal experience.

SLEEP

By Donald A. Laird

In Shakespeare's *Macbeth*, there is an eloquent tribute to sleep:

> Sleep that knits up the ravell'd sleave of care,
> The death of each day's life, sore labor's bath,
> Balm of hurt minds, great nature's second course,
> Chief nourisher in life's feast.

These inspiring lines offer a remarkably acute analysis of sleep. Many modern investigators have done research in this field, and their conclusions have often differed widely. Yet they all agreed on one point: that sleep is indeed nature's great restorer of both body and mind.

Certain aspects of sleep are more or less obvious. They include the absence of voluntary motion and the loss of awareness. But this is not the whole story by any means. There are also changes in metabolism, in the pulse rate, in blood pressure, in bodily temperature, in nerve functions, and in the nature of bodily reflexes.

The changes associated with sleep usually take place in a definite cycle. This is fairly uniform for a given species of the animal kingdom, including the species—*Homo sapiens*—to which we belong. In general, a certain number of active hours is followed by a certain number of quiet hours. The cycle is usually diurnal—that is, it extends through a day—and it is related to light and darkness. Sleep is also affected somewhat by the seasons, as we shall see. There are similar active and resting phases in plants, occurring in diurnal and seasonal cycles.

Sleep, or a state akin to it, is characteristic, then, of both plant and animal life. In the following pages we shall deal primarily with human sleep.

WHY DO WE SLEEP?

There were several theories at the start of the twentieth century to account for why we sleep. One of them assumed that nerve cells shrank during the waking hours. When they had shrunk so much that they no longer made contact with one another, people would become sleepy. Another theory held that some sort of toxin accumulated during waking hours. In time, this toxin would affect the nervous system so that it would slow down. According to the most widely accepted explanation—the so-called *cerebral anemia theory*—sleep came because the blood supply to the brain diminished.

As scientific evidence accumulated, it became apparent that none of these theories was valid. It is now known, for instance, that the blood supply of the brain actually increases during sleep. This is exactly the opposite of what the cerebral-anemia theory supposed. In fact, some of the restorative value of sleep may be due to this increased circulation.

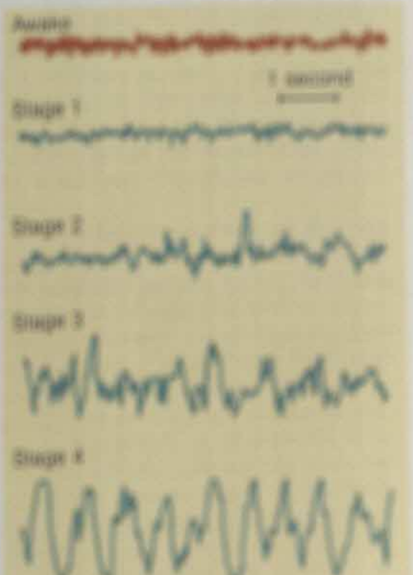
It is now firmly established, too, that the sleep-wakefulness-sleep cycle is due, in man and the higher animals, to special networks of neurons, or nerve cells, within the lower parts of the brain. In the late 1920s, Baron Constantin von Economo, of the University of Vienna, discovered that the centers regulating the sleep cycle were located in the area of the brain called the hypothalamus. It has since been established that the sleep-compelling center is less than one centimeter or so in front of the wakefulness center in the hypothalamus. In the middle 1940s, a Dutch physiologist, W. J. H. Nauta, demonstrated that the sleep-compelling center has priority over, or can inhibit, the wakefulness center.

An important part of the nerve network that regulates the shift from sleep to wakefulness was revealed by U.S. physiologist H. W. Magoun in the late 1950s. He showed that neurons in the brainstem, transmitting their impulses upward toward the brain, play an essential part in arousing the appropriate brain center to activity. This ascending network is now known as an *activating system*.

The sleep-wakefulness control centers in the hypothalamus and the activating system in the brainstem cooperate to bring about our daily seesaw between sleeping and waking. These specialized networks are responsible for the more easily observed bodily changes that take place in the sleep cycle.

As we pass from wakefulness to sleep and from sleep to wakefulness, significant changes occur in the brain waves—those ever-present bursts of electrical energy from the cortex, or gray matter, of the brain. The voltage as well as the frequency patterns of the brain waves change greatly as we go to sleep. They also vary with the depth of sleep and with the age of the person. It has been noted that the brain waves that occur during sleep are somewhat different during the first ten years of life than they are after that age. Among some elderly people, the sleeping brain waves are much like those of young children.

The brain remains active during sleep. The brain-wave patterns below are typical of wakefulness and of the stages of sleep, ranging from light sleep to deep sleep.



PREPARATORY STAGES OF SLEEP

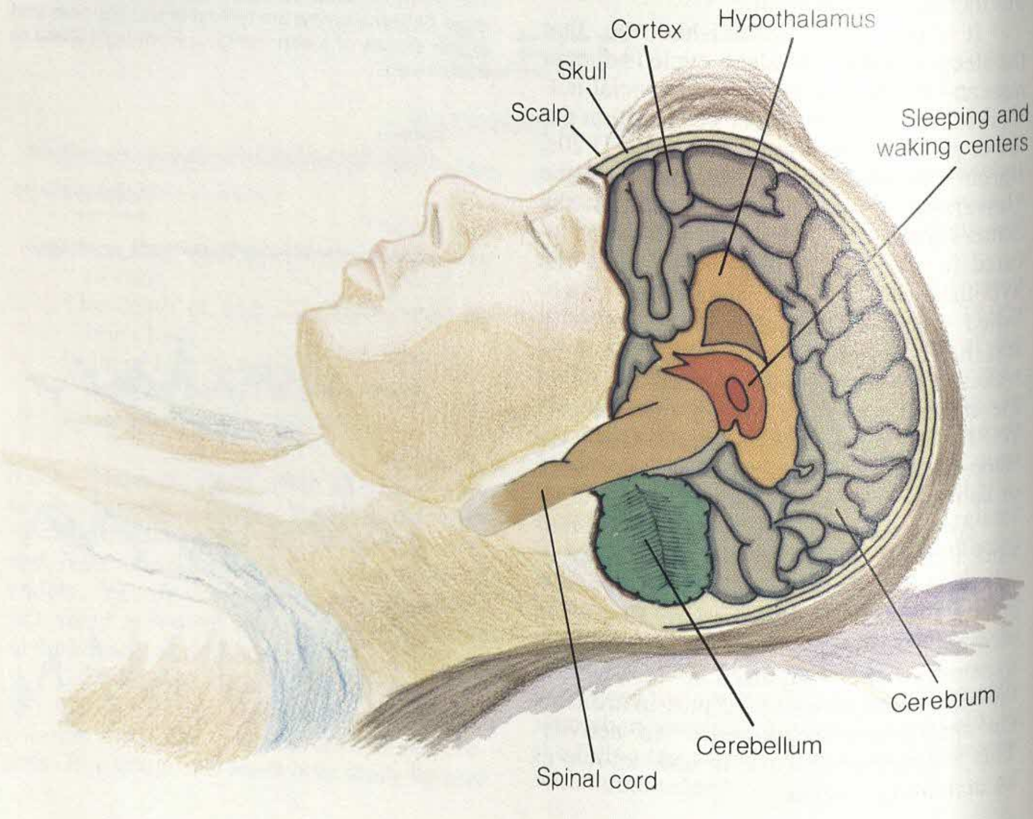
People do not, as a general thing, fall asleep suddenly. Instead, they pass through certain borderline states between full wakefulness and deepest slumber. These borderline stages are the only ones that a person is able to observe in himself.

The preparatory stage is marked by drowsiness, yawning, and stretching. It becomes difficult to concentrate, particularly on mental tasks. Drowsiness does not overcome every part of the body at the same time, but affects the different parts in a rather definite sequence. The muscles become sleepy first. Then the senses of hearing and seeing are dulled. The skin senses seem to be the last to be affected.

The first muscles to become drowsy are those of the legs. People are said to go to sleep feet first. Muscle languor then spreads upward, affecting in turn the muscles of the trunk, the arms, the neck, and finally the jaw and face. This sequence explains why, once we are in bed, the arms may be too drowsy to swat a buzzing insect, although the head may be moved from side to side in order to dislodge the pest.

When we wake up, the reverse order prevails: we wake up head first. We can turn the head to look at the alarm clock before we are able to reach for the clock and shut off the alarm. Shortly after we are able to move the arms, the legs are awakened. If we get out of bed hurriedly, before the legs have awakened sufficiently, our feet may become tangled up when we try to walk.

The human sleep-wakefulness-sleep cycle is due to special networks of neurons located in the hypothalamus. The hypothalamus is seated in the lower portion of the brain.



Muscle relaxation plays a key part in the onset of sleep. When small children who do not want to go to bed become overly active as bedtime approaches, they are probably attempting to fight off this preliminary muscle relaxation. Long-distance truck drivers, airplane pilots, and military guards are often instructed to tighten their leg and arm muscles intentionally when they feel drowsiness approaching. The resulting tenseness of the muscles makes it less likely that they will fall asleep on the job.

If muscle tenseness delays the onset of sleep, intentional relaxing of the muscles should help to bring on sleep. Emphasis should be placed on the neck, jaw, and face muscles, which are the last to relax in the normal course of events. Other factors, such as a darkened bedroom and a satisfactory degree of silence, will promote the coming of sleep. Because the skin senses are the last to become drowsy, every effort should be made to avoid stimulating them. The bed should be free of lumps, the pillows should be comfortable and the bedcovers should have no wrinkles.

Certain factors may delay the coming of sleep. The stimulation provided by a late mystery show on television, or a hard-fought game of chess, or an animated chat with friends may be delightful, but it will tend to keep us wide awake. Certain drugs, such as the caffeine contained in coffee and in the cola type of soft drinks, are also likely to overstimulate us.

HYPNAGOGIC STAGE

As the preparatory drowsiness becomes deeper, we enter upon the *hypnagogic stage* of light sleep. "Hypnagogic" comes from two Greek words meaning "bringing on sleep." To put it another way, we are two-thirds asleep, one-third awake. We no longer consciously direct our thinking. We become vaguely aware of peculiar ideas. There are fleeting dreams. At times, the dream activities of the hypnagogic stage seem to be so real that they are mistaken for actual fact. This results in hallucinations. A person is certain he sees things that actually do not exist. A sleepy automobile driver, for example, may try to steer around a nonexistent obstacle on the road ahead.

In this dream stage of going to sleep, a person usually has a vague awareness that he is dreaming. Some authorities believe that most of the dreams we remember occur during the hypnagogic stage.

These dreams may represent genuine creative activity. The words of "The Battle Hymn of the Republic" are said to have come to Julia Ward Howe while she was in the hypnagogic stage of sleep. According to the eighteenth-century Italian composer Giuseppe Tartini, the violin sonata that he called "The Devil's Trill" was based on melodies heard in a dream.

Most of us spend only a few minutes in the hypnagogic stage before entering upon a deeper form of slumber, in which we "sleep like a log." In the latter stage, according to experimenters, we are not aware of dreams, even though we dream.

DEEP SLEEP

The depth of the sleep that follows the hypnagogic stage has been measured by the amount of noise needed to awaken a sleeper. The loudest noise is usually required to rouse people after they have been asleep for about an hour. It takes almost as much noise, however, to waken a person after only a half-hour of sleep. This shows that we generally go into deep sleep rapidly, once we pass from the hypnagogic state. After two hours of this deeper sleep, only a slight noise may be needed to awaken sleepers.

Even in deep sleep, there are occasional movements of the body. Although many people imagine that they do not stir during sleep, experiments have shown that practically all sleepers shift positions many times during the night. The shift may be a major one, such as turning from one side to the other, without awakening. It may be only an arm or leg movement, presumably in the interests of comfort. During the latter half of the sleep period, stomach contractions, indicating hunger pangs, accompany body movements.

These movements are usually recorded by a simple apparatus that is attached to the top of the mattress. A recording stylus draws a line on a moving paper tape. The line is straight as long as the sleeper does not stir. It fluctuates when the sleeper moves. The more vigorous the movement, the more pronounced the fluctuation will be. There are usually few shifts of position during the first hour or two of deepest sleep. After that period there is usually a steady rise in the number of movements per hour. This is called a *crescendo sleep pattern.*

There seem to be seasonal variations in the depth of sleep, as shown by body movements. The least amount of movement takes place in the spring. There is most movement in the fall. The reason for these seasonal differences is not known.

Certain peculiar jerky movements of both eyes have been noted in sleep. They are known as rapid eye movements, often abbreviated REM. They have been recorded throughout the night. These movements first occur about two hours after the onset of sleep. Thereafter they come at more or less frequent intervals. In many instances, they are accompanied by dreams. Researchers have found this out by awakening sleepers right after the jerky movements were recorded.

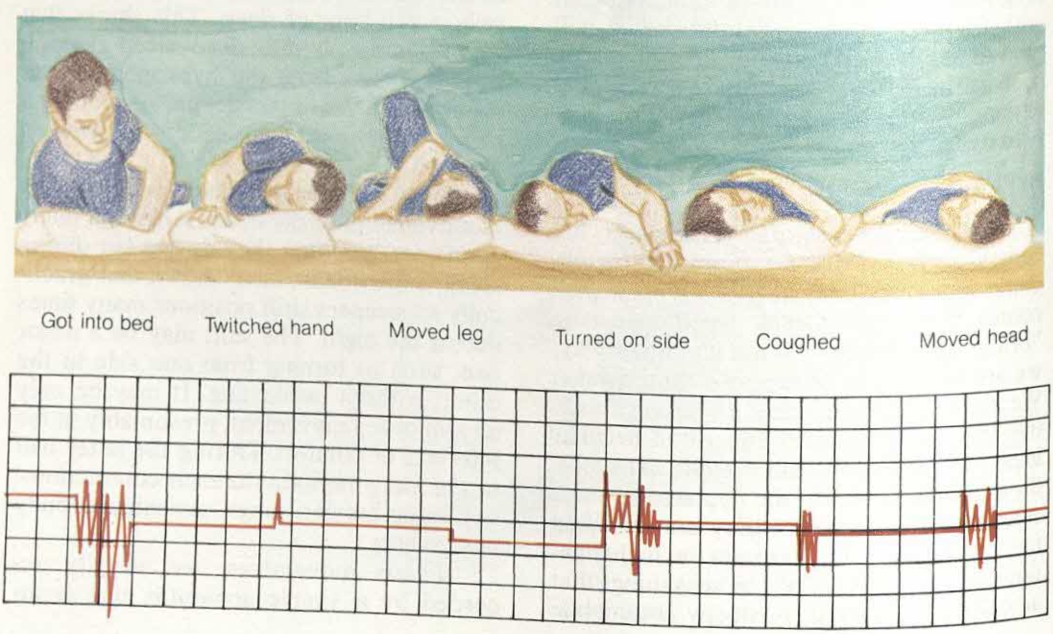
About one person out of every eight snores pretty regularly when he sleeps. The snore is produced by the fluttering of the soft structures (particularly the soft palate) about the mouth and nasal cavities. Generally, a person who snores in his sleep has his mouth open and is lying on his back, but that is not always the case. Allergy to certain substances may cause occasional outbreaks of snoring.

INTERNAL CHANGES DURING SLEEP

Many changes in the physiological activities of the body occur when one merely lies down. Some of these changes have to do with muscular relaxation. Others are brought about because the pumping of the blood is not affected as much by the force of gravity as it is in an erect position.

The total bodily metabolism, as shown by calories of energy consumed, is lowered when we rest in the horizontal position without being asleep. When we sleep in this position, it drops about 10 per cent more.

The movement of the body during sleep can be recorded by an apparatus that is attached to the top of the mattress. A recording stylus draws a line on a moving paper tape. The line fluctuates when the sleeper moves.



The pulse rate decreases when we lie down and keep quiet, while remaining awake. It usually slows down even more as soon as we fall asleep. Noises in the sleeping room have been found to speed up the heart rate temporarily. It also rises when the sleeper shifts his position.

Blood pressure generally drops most during the first hour of sleep. After that, it rises slowly, but seldom to the waking level. There are exceptions, however. Dreams about muscular activity may cause the pressure to rise even higher than the waking level. Sudden awakening by an alarm clock has also been found to cause an abrupt jump in blood pressure. If middle-aged and elderly people jump out of bed too suddenly, the extreme change in pressure may affect the heart.

The distribution of blood throughout the body is greatly altered during sleep. The blood vessels near the surface of the body are slightly dilated, permitting a greater flow of blood in the skin. This produces a flushed appearance, which can be observed even in a person who has fallen asleep while sitting in a chair. At the same time that blood flow increases near the body surface, it diminishes in almost all the internal organs. It increases, however, in the brain.

As more blood is shifted to the surface of the body in sleep, we become more susceptible to chills. Unless we are adequately covered, there will be an excessive loss of body heat. That is why we need warmer covering for the body while sleeping than while awake. In regions where the winters are particularly cold, it is often desirable to have a blanket under the bottom sheet in order to lessen heat loss there.

The internal temperature is lowered slightly during sleep. There are also changes in breathing. People do not take as deep breaths as they do while they are awake. This tendency is sometimes used as a guide to determine whether a person is actually asleep or pretending to sleep.

Perspiration is greatly increased when we are asleep, perhaps because of the increased blood flow near the surface. This increase in sweat is almost up to the level caused by strenuous exercise.

All these widespread changes in bodily processes are probably coordinated by nerve centers in the hypothalamus. The extent to which nerve functions are involved in sleep is shown by the drastic changes in reflex actions, such as the patellar reflex, or knee jerk. When a normal person is awake, the leg is jerked forward when the lower edge of the kneecap is tapped lightly. This knee jerk, it seems, cannot be produced during sleep. In fact, most bodily reflexes are more difficult to touch off during sleep and some seem to disappear entirely. The reflexes that regulate the distribution of blood, however, become more active than usual.

FUNCTION OF SLEEP

Sleep is obviously a restorer, but researchers have not been able to discover the exact nature of the processes involved. We do know, however, that after a night of deep sleep most people awake feeling refreshed and energetic. We also know that when a person is deprived of sleep, he is likely to feel certain unfavorable results the following day. If a moderate amount of sleep is lost, there are no significant effects on such physiological functions as metabolism. Simple mental operations, such as adding figures, are usually not affected by sleep loss, but the more complex mental functions almost always suffer. People also react emotionally. They tend to be more irritable, or to laugh or cry without apparent cause, if they have been on a short ration of sleep. After serious sleep loss, they begin to have hallucinations.

The amount of sleep needed depends upon the individual. The average requirement is as follows:

Babies	18 to 20 hours a day.
Grade-school children	12 to 14 hours a day.
Adults	7 to 9 hours a day.

Everyone should sleep enough so that he can waken in the morning feeling refreshed and in condition to do complex mental work.

Newspapers occasionally carry accounts of people who claim to have gone without sleep for years. When investigated,

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The sleeping patient above is being carefully monitored in a sleep research program. Detailed records are kept of temperature, pulse rate, eye motion, and other sleep activities.

these claims are shown to be without foundation. A person who says he can get along without sleep usually neglects to mention the many naps he takes, perhaps in a sitting position, during the day.

Lost sleep seems to be made up rapidly. In one experiment, people who had lost sixteen hours of sleep because they had been kept awake for two consecutive nights were allowed to sleep as long as they could the third night. They awakened refreshed after about eleven hours of sleep. One recalls the experience of the famous U.S. aviator Charles A. Lindbergh after his epic solo flight from New York to Paris in May 1927. When he landed at Paris, he had been without sleep for three days and nights. Yet it took him only ten hours of sleep to catch up on what he had lost.

CONDITIONS THAT RESEMBLE SLEEP

The hibernation of some animals differs significantly from their diurnal sleep cycle. In hibernation, the animal draws slow and shallow breaths for a time. The breathing then becomes faster and deeper; finally it subsides again into slow, shallow breaths. The animal does not store up energy during hibernation; instead, it consumes its own fat. This is converted into carbohydrate and then burned up to support the vital processes, which are at a low level when the animal is in this state.

People who are hypnotized often appear to be asleep, but this is not the case. The knee jerk and other reflexes that disappear in real sleep are still present in hypnosis. Most of the other internal changes occurring in real sleep are also missing. The spiritualist's trance is similar to hypnosis rather than to real sleep. Some authorities look upon such a trance as a form of self-hypnosis.

Narcolepsy, the "sleeping disease," is more closely akin to sleep. A person with narcolepsy falls asleep abruptly without preliminary drowsiness. He may be playing cards, waiting for a bus, or working hard when he suddenly goes into a sleeplike state, sometimes without changing his position appreciably. This sleep may last from a few seconds to twenty minutes. Often the person is not aware later that he had been

Electronic monitoring of a subject's brain waves and eye movements is basic to sleep research. This complex panel facilitates such readings.

UPI

asleep. He seems unable to recall dreams. Napoleon Bonaparte, who sometimes fell asleep while riding a horse, was probably a victim of narcolepsy. Some fatal automobile accidents have been attributed to the disease. It is suspected that it is due to some disturbance of the hypothalamus.

The more powerful drugs and anesthetics used to produce unconsciousness do not cause real sleep, though the person may pass into sleep before regaining consciousness. The same is true of the milder sedatives and sleeping pills which are used for treating insomnia. Some of these preparations produce a brief hypnotic effect. Others relax the voluntary muscles.

SLEEP DISORDERS

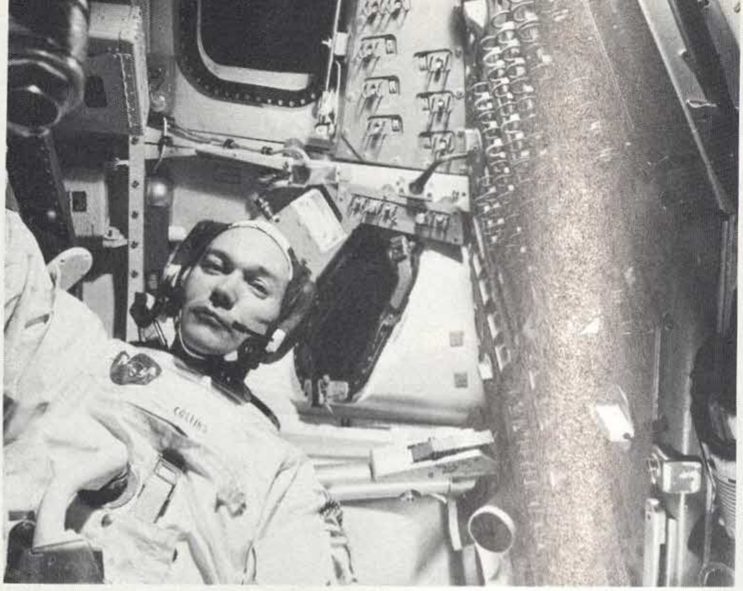
The sleep disorder called *somniloquism*, or sleep talking, is rather common. About 40 per cent of the college students who have been examined by investigators have been found to talk in their sleep. Usually they have no recollection of having done so. Sleep talking is considered to be a sign of poor sleep and of dream activity.

Somnambulism, or sleepwalking, is not so common as somniloquism. It is probably caused by emotional disturbances.

Night terrors, or *pavor nocturnus*, are attacks of anxiety which are associated with distressing dreams. The victim usually tosses in bed, and cries or moans without awakening. This disorder is more common among children than among adults.

Muscle cramps occasionally disturb sleep. The best remedy seems to be to stretch the cramped muscles by deliberately tightening the opposing muscles. In the case of leg cramps, walking around the room may "untie the knot."

Insomnia, or inability to get enough sleep, is one of the most common conditions about which adults consult a physician. Insomnia is the inability to fall asleep at night, periodic reawakenings throughout the night, premature waking early in the morning or any combination of the three. Insomnia is sometimes temporary and due to emotional strain. A student, for example, may not be able to sleep the night before an examination that he dreads. Some physical diseases are accompanied by insomnia. The most frequent cause appears to be anciety. A depressed person also frequently has trouble sleeping. The typical chronic insomniac is too emotionally tensed to relax and sleep and generally such a person can profit from psychological treatment.



Instrument panel in a simulated version of the command module of an Apollo spacecraft. All of the instrument arrangements in Apollo space vehicles represent remarkable examples of psychological research. They take into account the perceptions and abilities of the astronaut (shown here) so that he can operate the instruments properly under all possible conditions.

NASA

PSYCHOLOGY

by Donald A. Laird

The average person browsing through a technical article or book on psychology may come to think that this science is pretty far removed from everday life. Nothing could be further from truth, for the basic concern of psychology is human nature. It interests itself in such vital matters as the nature of the emotions; the way in which our senses become aware of the world about us; the problem of learning; and how the imagination works. In other words, the psychologist is primarily concerned with finding out what makes us "tick."

Psychology has an unusually wide range. Some topics, such as memory, attention, learning, imagination, motivation, personality, intelligence, and aptitudes, are more or less exclusively its own. It overlaps with physiology when it deals with certain other problems, such as: How do our eyes, ears, and other senses perceive the world? How are the ductless glands and certain parts of the nervous system related to fear, anger, worry, and other emotional states? How are the central parts of the nervous system, especially the brain, involved in the higher mental processes of memory, learning, and abstract thinking? Psychology encroaches upon the province of philosophy when it deals with questions like these: What is the nature of knowledge? How do we know what we know? What makes thinking logical? What determines moral conduct? Do we have inborn ideas of justice, honesty, distance, and other such abstractions?

For more than 2,000 years psychological teachings were by-products of the speculations and reasonings of philosophers. In the last century, several English and Scottish philosophers interested themselves particularly in the mind and inaugurated what became known as "mental philosophy." At about the same time certain physiologists, especially in Germany, began a series of experiments on sensations and illusions and on the speed of nerve inpulses. There were soon other experiments on memory and the time required for various kinds of thinking.

Modern scientific psychology was ushered in when men began to apply the physiologists' laboratory methods to some of the problems that had puzzled the philosophers interested in the human mind. The modern psychologist still speculates about human nature. He looks upon his speculations, however, as hypotheses that have to be either confirmed or rejected by experiments. The experimental method of psychological analysis has been extended to the study of animal behavior. It has been used to attack such problems as a cockroach's learning and the way in which a single-celled paramecium responds to its environment. Psychology, therefore, has come to concern itself with animal nature, as well, but is still primarily a human science.

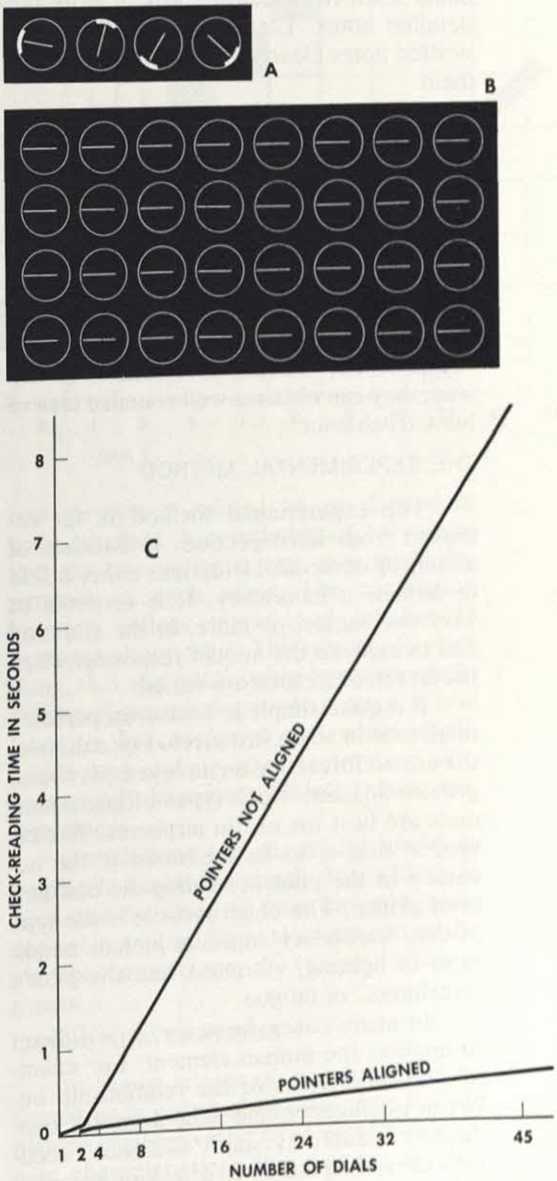
OBTAINING INFORMATION

People draw many psychological conclusions in their everyday talk without realizing that they are psychologizing, or making guesses about human nature. Some persons, for example, consider it a waste of time to study before going to bed. Others maintain that children with no brothers or sisters are always selfish. Scientific psychologists look upon conclusions such as these as *hypotheses*. They devise experiments to discover whether a particular conclusion has a good chance of being generally true for human nature. To do this, they use the recognized methods of science. They observe systematically under controlled conditions and they measure carefully. They repeat observations many times in order to be certain that the first observations were not in error. They are always on the lookout for negative instances. The findings have to be summarized. Their general plausibility has to be checked by logic and mathematics.

THE INTROSPECTIVE METHOD

The method of observation known as *introspection* is seldom used in any other science but psychology. When we speak of introspection, we mean that an individual carefully observes his own mental processes as they take place. He turns his attention inward to analyze his feelings, sensations, or thoughts. Introspection was the chief method used in psychology when it first developed as an infant science.

Using introspective methods, Sir Francis Galton discovered how people differ in their powers of mental imagery, or the process evoking mental images. He asked his acquaintances to think back to breakfast time and to introspect about the clearness of the mental images they could call to mind. A few people could "see" the table in their "mind's eye" as clearly as in real life. Others could not form visual images, although they could "hear" the rat-



Why it is important to set up effective patterns for dial pointers. The pointers in *A* are in the normal condition, pointing every which way. The pointers in *B*, also in the normal condition, are all aligned in the same direction (horizontal). It takes as long to check the positions of the 4 pointers in *A* as to check those of the 32 pointers in *B* (0.5 second). Graph *C* indicates the relative times required to check read various numbers of dials of aligned and unaligned types.

Adapted by permission from diagrams prepared by Aerospace Medical Division's 6570th Personnel Research Laboratory, Lackland AFB, Tex.

tling of the chinaware. A very few could imagine the odor of the coffee, but most were weak in images of odor and taste.

Selman A. Waksman, the discoverer of many antibiotics, found that he had faint imagery for sounds, but vivid imagery for sights. He applied this introspective information about himself by learning from books and demonstrations rather than from lectures. He realized that the only way he could learn from lectures was to write out detailed notes. Later he could "see" his written notes clearly just by thinking about them.

During the 1920s, a heated controversy was started by the U.S. psychologist John B. Watson, who urged that introspection should be discarded and only objective methods used to study human behavior. This controversy ended in a compromise. Psychologists now use objective methods whenever possible. But they supplement these methods by introspection to provide subjective, or "inside," information. In this way, they can obtain a well-rounded idea of human behavior.

THE EXPERIMENTAL METHOD

The experimental method is far removed from introspection. It consists of setting up controlled situations either inside or outside a laboratory. It is essential to vary one factor, or more, in the situation and to analyze the human responses when the factor, or factors, are varied.

It is quite simple to measure a person's responses in some instances. For example, the armed forces have employed psychologists to find out which types of instrument dials are best for use in airplanes. The response that is to be measured is the accuracy of the pilot in reading the dial at a brief glance. The chief variable is the type of dial. Secondary variables include conditions of lighting, vibration, and the pilot's "freshness" or fatigue.

In many cases, however, it is difficult to analyze the human element. For example, neighborliness or the relationship between intelligence and school grades cannot be measured as simply as a pilot's accuracy in reading a dial. In attacking complex problems, the experimental psychologist has to spend a great deal of time in devising reliable methods to measure human reactions. This type of psychological study has been helped greatly by advances in the mathematics of statistics and probabilities since about 1925.

Experimental psychology owes much to the pioneer efforts of Sir Ronald A. Fisher, an English geneticist, in applying mathematical methods to the setting up of experiments. He made it possible to design experiments in such a way that the influence of different variables could be controlled. Sir Ronald's methods have been of great use in all sciences, but they have yielded particularly fruitful results in the field of psychology.

THE STATISTICAL APPROACH

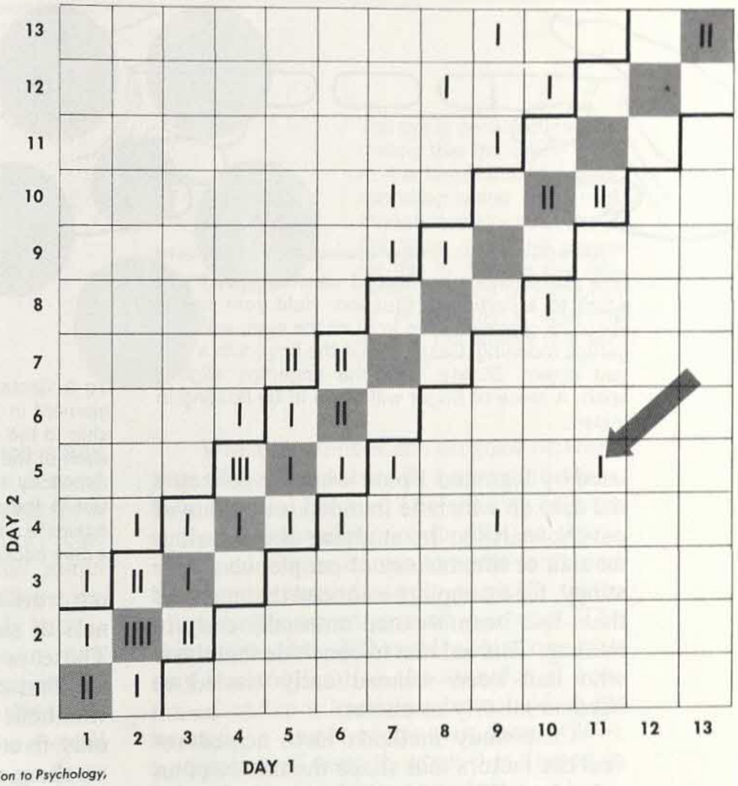
Are people who live in small towns more neighborly than those living in big cities? Standards for measuring neighborliness are needed to get an answer. The amateur might be satisfied to judge that people in big cities tend to be only "slightly" neighborly, while those in small towns are "more" neighborly. But how much is the difference between "slightly" and "more"? This example shows the need for summarizing observations by means of a calculated number called an *index number*, or *average*.

An average, or *mean*, is the simplest statistical application to such problems. How old is the average child when it starts to talk? The mean will tell us. Compiled observations show that the average one-year-old says a few words, but does not seem to know their meaning. The average year-and-a-half knows more words, and uses many of them properly. By age two, the average child can use sentences, and asks an average of sixty questions a day.

A large number of subjects have to be observed for each age to find an average that is trustworthy. Only a few children will be exactly at the average for their age. Nearly half will be above it, and an equal number will be below it.

The amount of scattering above and below any mean has to be taken into consideration. A mean is obviously not trust-

Diagram illustrating correlation. Forty-nine subjects were given a test of susceptibility to hypnotism on two separate days (Days 1 and 2 in the diagram). A score from 1 through 13 was given for each test, as indicated on the sides of the diagram. Each of the 49 subjects is represented by a vertical mark in a given box in the diagram, the box indicating the scores that he made in the two tests. For example, the subject indicated by the arrow had a score of 11 on the first day and 5 on the second. If all 49 subjects had identical scores—say 2 or 5 or 8—on the two days, all the vertical marks would be located in the shaded boxes, showing perfect correlation between the two sets of test results. As it is, the degree of correlation was high. Most of the vertical marks are concentrated in the boxes between the solid lines, indicating a difference of not more than 1 point in the scores for the two test series.



Adapted by permission from diagram in Hilgard, *Introduction to Psychology*, Harcourt, Brace, & Jovanovich

worthy if the scattering is great. The degree of scattering can be measured statistically by formulas for computing the *standard deviation* and error of estimate. When averages are compared for different groups, the standard deviations indicate whether or not the differences are significant.

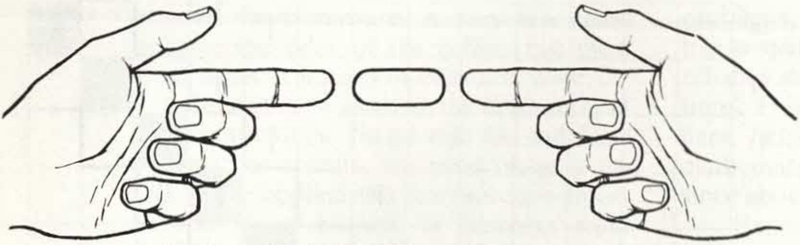
Averages and indexes of scattering give the psychologist a basis for *scaling*, or arranging in a graduated series. This gives numerical values for such intricate qualities as neighborliness, or prejudice, or intelligence, or other such characteristics. The numerical values used in these psychological standards should indicate steps of equal distance along the scale. School marks given by teachers, by way of contrast, are not computed in scaled units. The difference between a grade mark of 80 and 85 may be much greater or much less than the difference between 90 and 95.

Correlation is another important statistical method widely used in psychology. Correlations measure the degree to which one variable is related to, or dependent upon, another. A correlation of 1.0 means that the two variables are completely dependent on each other. The correlation between college marks and intelligence averages about 0.60. This shows, for one thing, that the relationship between marks and intelligence is not due to chance. It also leads to the conclusion that while intelligence does count, other factors are also exceedingly important in determining college grades.

Correlations are especially useful in helping to decide if a conclusion is likely to be generally true, or true for only some special instances. They also serve to evaluate the importance of various achievements.

CASE-STUDY METHODS

In many instances, psychological information is obtained by analyzing the life history of people who have some predominant characteristics. This was the method



Adapted by permission from Stagner & Karowski, *Psychology*, McGraw-Hill

How our senses may mislead us when they try to adapt to a particular situation. Hold your hands about 25 centimeters in front of the eyes, with fingertips touching. Gaze beyond the fingers to a distant object. Slowly draw the fingertips slightly apart. A piece of finger will seem to be floating in midair.

used by Sigmund Freud when he collected the data on which he founded his system of psychoanalysis. In studying the developmental, or life, history of people who were stingy, for example, he noticed that many of them had been weaned unusually early in infancy. This led him to conclude that those who had been weaned early tended to become miserly as adults.

Case-study methods have helped reveal the factors that shape the nature of an individual. This is particularly true in such unusual conditions as mental disorder, crime, delinquency, and psychosomatic disorders (mentally caused bodily disorders). Conclusions from case-history studies are usually looked upon as tentative. They must be confirmed by experimentation and statistical analysis.

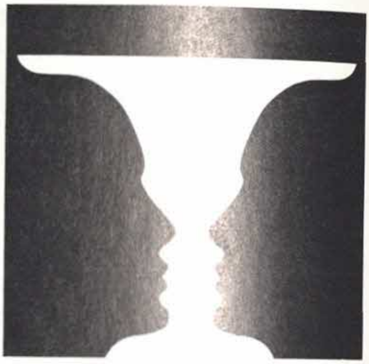
By applying the methods of introspection, experimentation, statistical analysis, and case-history study, psychologists have amassed a vast amount of information about human nature. We shall now consider some of their findings.

BECOMING AWARE

SENSATION AND PERCEPTION

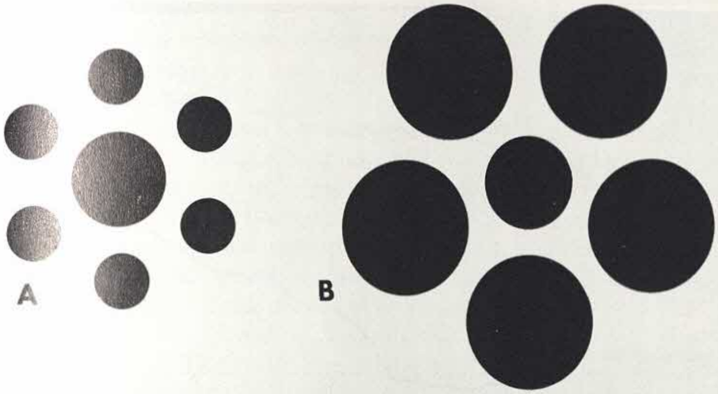
The fundamental principles that hold true for human nature, in general, form the basis of general psychology. This science deals with the ways in which people become aware of their world and how they react to it.

The simplest forms of awareness of our world come about by way of the channels of sensation that we call the senses. These psychological factors were among the first to be experimentally studied. It was believed at one time that there were only five senses – seeing, hearing, tasting, smelling, and touching. Introspections, confirmed by clinical and physiological studies, have shown that this list is quite incomplete. Taste really consists of four separate sensations – sweet, sour, salt, and bitter. There are distinct sensory cells, or receptors, on the tongue for each of those four sensations. In adults, the only taste buds sensitive to sweet are near the tip of the tongue. The taste buds at the back of the tongue are sensitive only to bitter. Often what we ordinarily call "taste," such as the "taste" of coffee, is really a mixture of taste and smell. When the nostrils are closed and the coffee is not smelled, it tastes bitter.



To a Gestalt psychologist, the perception of one element in a situation depends upon its relationship to the other elements in the situation. Thus if each of the profiles in the above drawing were to appear by itself, each would look like a profile only. But in the drawing, we see either two dark faces against a white background or a white vase against a dark background.

What we call "touch" is also actually made up of four distinct senses – warmth, cold, pressure, and pain – which are now called the *skin senses*. Each of these skin senses has its own separate sensory cells, or end organs, scattered throughout the body surface. These receptors are not scattered uniformly. The fingertips are much more sensitive to pressure than is the back of the hand, and the middle of the back is the least sensitive.



The eye is deceived into estimating that the center circle in *A* is larger than the corresponding center circle in *B*, though actually both are of the same size. The reason for this is that the eye estimates the size of an object by contrasting it with the sizes of the objects that surround it.

Important sensations, of which many people are not usually aware, are derived from the muscles and joints, and also from the semicircular canals in the inner ear. The sensations from muscles and joints are called *kinesthetic*, because they give us information about active bodily movements. "Kinesthetic" comes from two Greek words meaning "perception of movement." The sensations from the semicircular canals inform us about the overall motion of the body, and they also guide us in maintaining equilibrium.

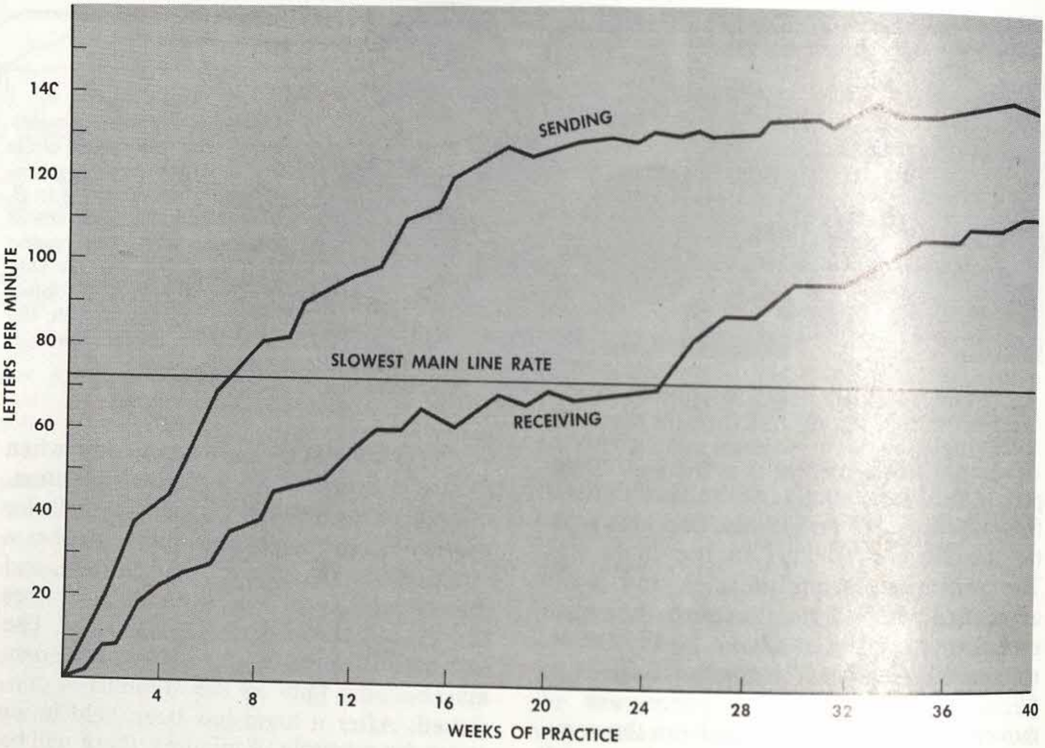
There are very few sensations from the internal organs or passages. The throat has receptors for warmth, and will give a burning sensation when overly hot food is swallowed. If, however, the same hot food is swallowed quickly, the warmth will no longer be sensed after the food is halfway into the stomach. The internal organs seem to be sensitive only to stretching or tearing. The sensation of hunger is associated with powerful automatic contractions of the empty stomach. The sensation of thirst comes from extreme dryness of the throat.

Our sensations do not always give us a correct impression of the world about us, for there are dozens of illusions, or false sensory impressions. Vertical lines look longer than they are. It is difficult to judge whether an unseen source of sound is directly in front of us or directly behind us. A pinpoint of light seems to move and form a line when viewed in a dark room. Motion pictures are illusions: they are actually a rapid sequence of still pictures.

When the senses are fatigued or when they adapt themselves to a given situation, they often mislead us. The sensory cells for tasting and smelling tire rapidly, so that a strong odor soon comes to seem faint, and then is not sensed at all. A pickle tastes sourest after we eat something sweet. The skin senses also shift rapidly. A strong pain may become faint as the stimulus is continued. After a hand has been held in ice water for a couple of minutes, there will be a sensation of warmth when it is dipped in water that is at room temperature.

Perceptions are higher up in the scale of our responses than sensory experiences. Perceptions are the meanings we get from sensory experiences. We sense a series of sounds and perceive that they are the voice of an acquaintance, or Beethoven's Minuet in G, or something else that has a meaning for us.

The span of an individual's perception is limited. In reading, we can catch the meaning of only about a half-dozen words at a time. We can pay attention to only two or three people at a time in a social group. Our perceptions are selective, as well as limited. We heed the stimuli that interest us most or that happen to be so intense that they force themselves upon our attention. We usually do not notice the sensations caused by our clothing or coming from our muscles and joints. In a social group we are most likely to perceive the voices of friends. We tend to ignore the voices of those who are strangers to us, unless these voices happen to be loud.



This diagram shows the progress of an apprentice telegrapher in learning to send and receive messages. Note the "learning plateaus"—periods of little or no gain in skill. The diagram shows the results of one of several experiments on learning curves carried out by Noble Harter toward the end of the nineteenth century. These experiments represented a landmark in research on learning curves.

The meanings we derive from our sensations have been slowly built up by our previous experiences. John Locke pointed out, nearly 300 years ago, that we do not have innate ideas of such perceptions as "roundness," "squareness," "distance," "honesty," and so on. Such meanings are acquired from experience. The more experience a person has, the richer the meanings will be. A common example is the way music or literature "grows on one" as one becomes more familiar with it.

In recent years, certain psychologists have called attention to the importance of the total situation in determining what our perceptions are. These psychologists formed the school known as *Gestalt psychology. Gestalt* is a German word meaning "form," or "pattern" or "organization into an integrated whole." According to Gestalt psychology, meaning is the result of all the forces at work in forming a given perception. A piece of white paper, for example, is perceived as whiter when seen against a black background. The way we react to the phrase "Don't be funny" will depend upon whether we like or dislike the person who says it.

LEARNING AND MEMORIZING

In learning, remembering, and thinking, the sensory nerves may play only an incidental role. Learning, broadly speaking, is the ability to profit from past experience. A very young child learns not to touch a hot radiator, because it burns him. In this case, the unpleasant sensation of burning is the direct stimulus. A few months later, he learns to keep his hands off all objects which his parents call "hot." The word "hot" thus becomes a substitute stimulus for the actual sensation of burning. In this conditioned-response type of learning, a substitute stimulus becomes almost as effective as the natural sensation. Sensory-motor learning, in which action is directly governed by sensation, is more complex. It is the basis of many skills, such as typewriting, playing a muscial instrument, and doing various routine operations in factory and office. Ideational learning, involving the acquisition of ideas, is considered the highest type. The study of grammar, for example, involves ideational learning.

Some general laws of learning have a wide application. According to the law of effect, learning becomes easier when the response brings satisfying or pleasurable results and it is slowed down when the results are annoying or unpleasant. School children learn how to add faster when they are praised for getting correct answers than when they are reproved for getting the wrong answers. According to the law of exercise, or frequency, the more times a new response is repeated, the better it is learned. This is illustrated by practice in typewriting or on a musical instrument.

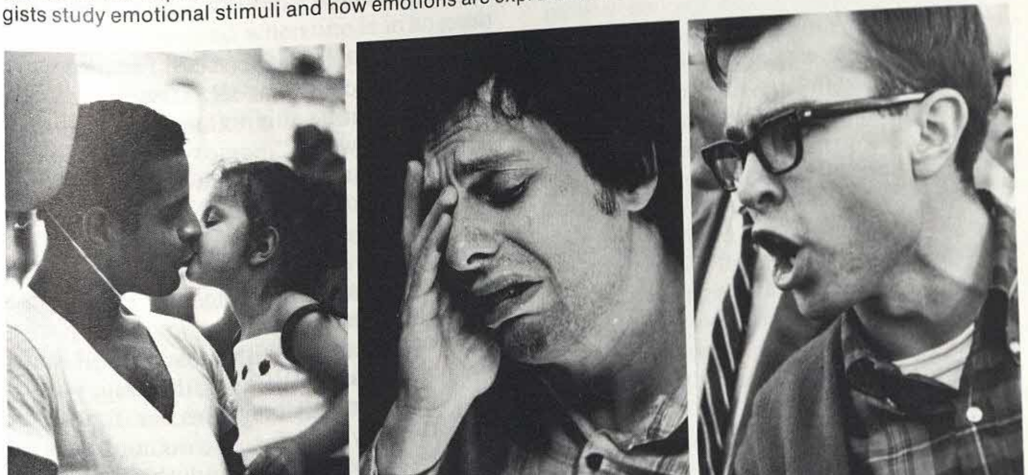
The rate at which a person acquires a new skill is called his *learning curve*. It typically shows a little gain in speed and a steady increase in accuracy with successive weeks of practice. The rate of gain is not uniform from one week to the next. The gain is usually greatest in the first couple of weeks. After a few weeks of practice, it may become so slight that the learner is temporarily discouraged. These occasional periods of no gain, or possibly actual slump, are called *plateaus* in learning. A plateau usually indicates that a person should practice in a different way. It does not necessarily mean that he is incapable of further progress.

We generally gain speed faster if we space out our practice periods. A spaced practice of a half hour each day tends to be more effective than a concentrated practice of three hours one day in the week. Concentrated practice may cause a plateau.

Learning is helped when the learner plays an active rather than a passive part. Reciting a lesson is better than merely hearing someone else recite. It is better to take notes of a lecture than to simply listen to it.

Overlearning is important if learning is to last a long time. Overlearning means more practice, or review, than is needed to barely master a topic. If a child practices

Emotions are expressed in many ways, including facial expression. Psychologists study emotional stimuli and how emotions are expressed or controlled.



Sherry Suris, Rapho/PR

Rapho/PR

Bob Combs, Rapho/PR

the multiplication tables after he has barely learned them, he will remember them longer. A large part of school learning slips away after graduation because it was not overlearned in school.

The laws of effect, exercise, spaced practice, and overlearning all apply to memorizing. We can learn things by heart more easily if we adopt certain simple procedures. Trying to remember makes remembering easier. Getting a clear perception of what is to be memorized also helps. This is done by directing attention sharply on the object or fact to be remembered and keeping it directed in this way for some time. Forming mental associations with the new object or fact gives it more meaning and thus increases the chances of recalling it later, for meaningful memories last the longest. Pleasant associations often cause impressions to be better remembered.

The German psychologist Hermann Ebbinghaus found that facts are forgotten with great speed within a few hours after they have been memorized. The curve of forgetting shows that we are likely to forget more during the first day after memorizing than we do in the following thirty days. This can be applied in studying. Lessons can be reviewed the day after they are first studied, to offset the rapid initial forgetting that seems to be inevitable.

THINKING

Thinking ranges from simple daydreaming all the way to creative problem-solving. Our mental activities of sensing and perceiving depend upon some external stimulus, but the higher mental processes called thinking are usually touched off inwardly.

Recollecting calls previous experiences to mind and starts off a chain of mental associations. We may begin by recalling a demonstration of the laws of inertia in physics. This suggests an automobile accident where the brakes failed, which in turn suggests a hospital, and so on. Neither automobiles, nor brakes, nor hospitals have been pointed out to us by our senses. They have been present only as mental images.

Jumping from one thought to another is an illustration of *free association,* or uncontrolled thinking, a characteristic of daydreaming. Most human thinking is of this uncontrolled, or mind-wandering, type.

Directed, or *problem-solving,* thinking is considered the highest type. Our thinking is directed when we plan what to do this weekend, though we may lapse into daydreaming about it. Problem-solving is involved when the housewife plans how to use leftovers for a meal or when a student decides what courses to take next year. The highest forms of problem-solving thinking revolve around meanings and conceptions—abstractions rather than images of concrete things. A very practical person might think in concrete images of a particular physical movement he has seen. A scientist, viewing the same event, would possibly muse about the laws of inertia. Problem-solving proceeds by imagining new relationships between the abstractions. Often a new relationship is discovered by a sudden flash of insight.

In talking about perception, memory, and thinking, I may have given the impression that they are separate faculties. The terms "perception," "memory," and "thinking" are simply labels for mental functions that are singled out for study, one at a time. Actually, these functions are intertwined and interrelated, for we perceive, memorize, and think all at the same time.

As a matter of fact such functions are not really faculties at all. If we are to be strictly scientific, for example, we should not use the word "memory." It would be more accurate to use the word "remembering," which simply implies that certain brain cells are at work in a certain way. In like manner, it is more correct to speak of someone as acting intelligently rather than as having intelligence.

A comparison with muscles will make the point clearer. Walking, dancing, pulling and lifting are all activities, or functions, performed by muscles. We do not have one muscle for walking and another for dancing; walking and dancing are simply different activities of the same muscles. Similarly, mental activities such as remembering or thinking involve different activities of the same nerve cells in the brain.

FEELING, EMOTION, MOTIVATION, AND FRUSTRATION

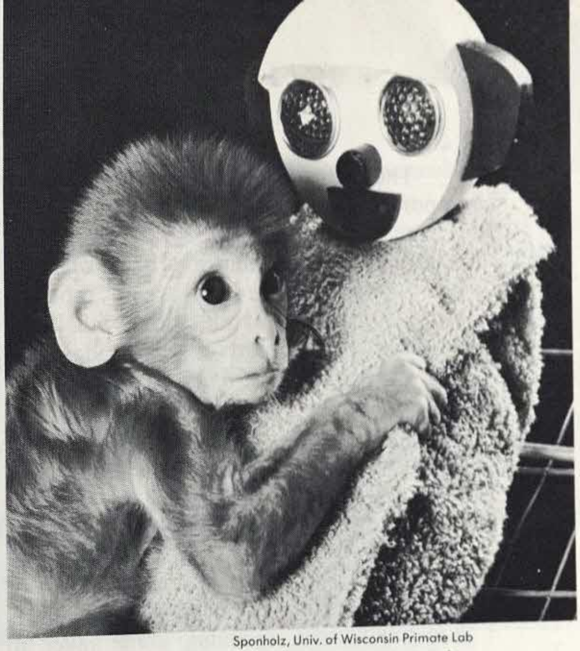
The pleasantness or unpleasantness that accompanies many sensations and perceptions is called *feeling tone.* A sweet taste is usually pleasurable, but it may be unpleasant if it is intensely sweet. Similar pleasant or unpleasant feeling tones accompany the other sensations. As a rule, extremely intense sensations tend to arouse unpleasant feelings. Feeling tone may also be aroused by the recollection of previous experiences. We probably have very few mental states that are neutral in feeling tone.

The pleasantness or unpleasantness is generally a subjective experience, observed by introspection, but this is not always the case. Muscles relax when there are pleasant feelings, and become tense with unpleasant feelings. We adopt a definite type of bodily posture when we approach a pleasant stimulus or when we withdraw from an unpleasant one.

Emotions are similar to feeling tone in that they are pleasant or unpleasant. They are much more intense, however, since they represent stirred-up states of mind. Fear, anger, love, surprise, disgust, and contempt are examples of emotions. Bodily changes are marked when one is in an emotional state. Moderately strong emotions are considered beneficial, but intense emotions often block thinking and produce irrational behavior.

The stirred-up condition and the corresponding bodily changes are inborn responses. However, learning plays a large part in determining what situation is to touch off the emotional response. For example, some people acquire a conditioned response to lightning, so that they are in a panic when they listen to an announcer forecasting a thunderstorm. Most of the situations that arouse our emotions are not natural stimuli. They are substitute stimuli to which our emotions have been unintentionally conditioned.

When psychologists speak of *motivation,* they have in mind the various needs and desires that make us want very much to do a certain thing. We may be motivated temporarily by perceptions, such as hunger or thirst, that drive us to neglect other activities in order to eat or drink. We are motivated positively when we are drawn into activities we find pleasurable, and negatively when we avoid unpleasant things.



Sponholz, Univ. of Wisconsin Primate Lab

A fascinating series of experiments conducted by Dr. Harry Harlow, an expert in animal psychology, showed that baby rhesus monkeys would accept substitute mothers made principally of wood, wire, and terry cloth. The soft and yielding cloth of the "mother" provided "contact comfort."

Scientists believe that the principal motivation in animals comes from physiological needs connected with hunger, thirst, sex, and the emotions. The motivations that seem to have the most pronounced long-term effect in human behavior seem to develop from our social associations with other humans. People who "belong to the same crowd" usually share many motives. One closely knit group of teen-agers may be motivated to get good school marks, another to have fun, another to win more social prestige, and so on.

Research in social psychology indicates that a widespread motive at the present time is the desire to be popular with others. The increase in this motive has been attributed to social changes resulting from the growth of the population and the increased industrialization of our culture.

The right motivation has been found important in determining achievement. One reason why intelligence tests correlate only 0.60 with college marks is because some highly intelligent students are not motivated to study hard, while some with lower intelligence work hard for good grades.

The phrase *level of aspiration* refers to the intensity of a person's motivation in a certain effort. People with high levels of aspiration are sometimes overmotivated. This leads them to become overemotional about possible failure when they reach a plateau in achievement.

Frustration is a stirred-up state of hopelessness. It results when a person is prevented from reaching some level to which he aspired or when he is prevented from satisfying his physiological needs.

PERSONALITY

Personality is the end result of the typical ways in which a person reacts: the product of his motivations, emotions, feeling tones, style of thinking, and attitudes. Personality is partly inborn, partly acquired. Such biological factors as the endocrine glands and the nervous system are largely responsible for the inborn aspects. The acquired aspects are picked up chiefly from the people with whom we associate.

Parapsychology is one of the specialized fields of study within psychology. Here a young child is being tested for ESP, or extrasensory perception.

Institute for Parapsychology, Durham, North Carolina

There are certain changes in personality as we pass from decade to decade through life. They usually reflect the ways in which we have responded to frustrations. As a rule such changes are slight.

The American psychologist Raymond B. Cattell has drawn up a list of twelve primary traits, or *source traits*, which give a complete picture of a person's personality. Each trait represents a scale, ranging from one extreme to another – for example, from independence to dependence, from maturity to childishness. The average person would be midway between the two extremes in the case of a given trait.

Here are his twelve primary traits:

1. Participating	ranging	to	Withdrawn
2. Clearheaded	"	"	Dull
3. Mature	"	"	Childish
4. Dominant	"	"	Submissive
5. Enthusiastic	"	"	Melancholic
6. Sensitive	"	"	Poised
7. Socialized	"	"	Boorish
8. Independent	"	"	Dependent
9. Adventurous	"	"	Fearful
10. Fatigued	"	"	Vigorous
11. Excitable	"	"	Phlegmatic
12. Accepting	"	"	Suspecting

THE SCIENCE OF PSYCHOLOGY

The body of psychological knowledge has become so large that no one person can be well informed in all fields. Specialization has become inevitable.

SPECIAL FIELDS

Here is a summary of some of the specialized fields of psychology:

Physiological psychology deals with the biological factors that help shape human nature. The early work in this field was mostly concerned with the structure of the sense organs and their connections with the central nervous system. About 1915, Walter B. Cannon called attention to the role of the endocrine glands, especially the adrenals, and the autonomic parts of the nervous system in emotional states. Physiological psychology also deals with the electrical activity of the nerves and of the brain itself in various mental states.

Children often express their ideas and feelings through play. What a child reveals in play activities can greatly help a psychologist to understand the child's emotional development and any problems that exist.

Federation of Jewish Philanthropies

Differential psychology concentrates on the differences between individuals in abilities and in mental makeup. This field is at the opposite pole from general psychology, which deals with ways in which most people are alike. Conditions such as color blindness belong to the field of differential psychology. The major work, however, is in less spectacular individual differences, such as those in intelligence, mechanical aptitude, and personality. This field is also concerned with the extent to which differences are inborn or acquired and how they can be altered by training.

Child psychology was one of the first special fields to be cultivated intensively. It studies the nature and development of individuals from birth through adolescence, or the teen years. The findings in this field have had a profound influence upon child-rearing teachings and educational practices. Our earlier examples of norms for learning to talk were taken from this field.

Educational psychology uses psychological approaches and methods in dealing with education from the kindergarten through graduate college. It is generally regarded as the oldest application of psychology. The first psychologist to devote full time to this work was Edward L. Thorndyke.

In educational psychology, the psychology of learning and memory and of the thought processes is widely applied. Psychological methods are used in testing for individual differences and also in measuring the results of various educational practices. The psychology of the emotions and personality is applied to help students develop better mental health.

Intelligence testing measures the all-around mental "horsepower" of an individual. The first series of intelligence tests was developed by the French researchers Alfred Binet and Théodore Simon in 1905. In 1916, Lewis M. Terman, Stanford University psychologist, and his colleagues introduced large-scale measuring of intelligence in the United States. Today intelligence tests are widely used. The most commonly used tests are given in groups, and require the ability to read and write. There are performance tests, however, which do not depend upon reading or writing. In all, there are several hundred different tests, including those for personality, emotions, prejudices, muscular skills, interests, and artistic judgment. The sale of test materials is now restricted to people who trained to use and interpret them.

Animal psychology uses objective, or behavioristic, methods to study learning and rather simple psychological functions in animals. Experimenters have found that animals generally use trial-and-error methods, although some chimpanzees have occasionally shown signs of insight in solving problems. Some questions in physiological psychology can be studied by surgery on the glands or nervous systems of animals. Most of the work in animal psychology is on theoretical problems. One team of animal psychologists, however, specializes in training small animals to perform.

Legal psychology deals with the accuracy of testimony and with psychological factors in crime and delinquency. Many prisons have staff psychologists who are occupied with the rehabilitation of prisoners. Lie-detector tests, which register bodily changes associated with the emotions when lying, have received much publicity in crime detection, but are not generally accepted by courts as legal evidence.

Vocational psychology helps a person choose a vocation in which he is interested and for which he has marked ability. It follows him through the training period and finally helps him make a satisfactory adjustment on the job.

Industrial psychology applies psychological methods and information to factory and office work. It deals with job-training methods, fatigue reduction, efficient work procedures, worker motivation, morale, the selection of workers, and advertising and selling. This field has been expanding rapidly, and there is much specialization.

Clinical, or *abnormal, psychology* is closely related to psychiatry. Clinical psychologists specialize in the study and treatment of mental disorders. More psychologists are engaged in this field than in any other specialized field at present.

Parapsychology, formerly called psychic research, deals with mind reading, thought transference, and extrasensory perception, or the perception of objects that are not present to the senses. Only a few psychologists are active in this field, but the general public shows great interest in it. There has been much well-planned research, but to date there is no generally accepted proof of the existence of mind reading and similar powers.

Social psychology is concerned with the way groups develop and function and with the influence of group membership upon the mental life of the individual. In a group, people are associated and interact with one another. The name "group" is applied not only to clubs and societies, but also to neighborhoods, classrooms, and homes. The field of social psychology has been expanding rapidly, largely by using methods of psychological measurement to study group forces and interactions.

Human relations and *group dynamics* are offshoots from social psychology. They deal with factors that make for harmonious relations, not only between the members within one group but also between various groups. Since 1950, more than a dozen research centers have been established in these fields at leading universities. Their findings have already revolutionized our ideas of leadership. They have indicated ways to bring about greater harmony between groups and lessen prejudices.

Engineering psychology, ergonomics (from two Greek words meaning "work management"), and *human factors* are three closely related fields, brought into being by automation and the space age. Their objective is to design equipment which will be best adapted to human requirements. Thousands of man-hours of psychological research are required, for example, before a manned space vehicle is launched.

HOW TO BECOME A PSYCHOLOGIST

The training of modern psychologists includes not only a number of courses in psychology but also an adequate grounding in physiology, anatomy, physics, and sociology, and a study of research methods, particularly the mathematics of probabilities. A psychologist's training usually requires three years of concentrated graduate study after completeing the ordinary college course. It leads to the degree of doctor of philosophy (Ph.D.). Ph.D.'s in clinical psychology usually spend an extra year as interns in mental hospitals or clinics.

In our discussion of the various branches of psychology, we have dealt with some of the important fields in which fully qualified psychologists serve. There are also many job openings for people with a master's degree in psychology, such as in giving mental tests in employment offices and school systems.

PSYCHOSOMATIC MEDICINE

by James Hassett

A football coach knows the team's fans blame him for the losing season. He worries that he will be fired. His ulcer begins to bleed.

A doctor is caught in a traffic jam. An injured patient waits in the hospital for an operation. The doctor's blood pressure rises.

A child hates his older brother but keeps his anger hidden behind a smiling face. Forty years from now, he may suffer from arthritis.

Ulcers, high blood pressure, arthritis—these are physical illnesses. But they can be caused by mental and emotional problems. Allergies, skin rashes, headaches, and diarrhea can also be caused by emotional problems.

Physical illnesses in which mental conflicts play a role are known as *psychosomatic diseases*. The term combines the Greek roots *psyche,* meaning soul or mind, and *soma,* meaning body. Many people misuse the word psychosomatic. If a girl gets a stomachache before a big date, her brother may smile knowingly and say, "It's psychosomatic." True, her nausea is psychosomatic, but that makes it no less real. To tell her that "it's all in your head" is quite inaccurate. The problem may begin in the brain—in this case, with some uneasiness about a date—but this is only the beginning of the story. Messages from the brain to other parts of the body lead to physical problems—in this case, to a feeling of nausea.

There are, of course, people who fake physical problems to avoid responsibility. Such individuals are not suffering from psychosomatic disorders. Other people may have physical symptoms with no organic basis. A person may become blind, deaf, or paralyzed despite the fact that there is nothing wrong with his body. Such patients are said to be suffering from hysteria, a type of severe neurosis. Again, this is not a major area of psychosomatic medicine.

Psychosomatic medicine deals with individuals with true physical symptoms that are at least partially caused by psychological stress.

STRESS AND DISEASE

As early as the 1930's, researchers noted that the stressful events of everyday life—pregnancy, a new job, and so on—seemed to lower the body's resistance to disease. Skin disease, colds, and even tuberculosis were more likely to strike those who had recently experienced life crises than those who were living more peaceful lives.

More than a quarter of a century later, scientists at the University of Washington in the United States undertook systematic studies of this phenomenon. They asked many people to rate various life events in terms of the amount of readjustment required. Ultimately, the researchers developed a scale of "Life Change Units" associated with each event. According to this scale, most people feel that the death of a spouse is about twice as stressful as getting married, and five times as stressful as changing to a new school. Notice that stress is associated with positive, happy events as well as with negative and sad events.

Many later studies in a number of countries found surprisingly similar results. There are, of course, some differences in the way different cultures perceive the same events. Similarly, the values given in the chart will not apply precisely to every individual within a culture. Nonetheless, life change scores provide a good approximation for studying the relationship between stress and disease.

Once the scale was developed, it was a fairly simple matter to have people check off the events that applied to them for the last year or so, and then see whether people with high life change scores developed more diseases than people with lower scores. And, in fact, they did.

For example, in one study, about 2,500 crew members of several U.S. Navy cruisers were asked to fill out life history forms before they went to sea. Their medical records were examined at the end of a six-month cruise. Sailors with life change scores of 88 or less for the six months preceding the cruise had about 7.7 illnesses per 1,000 men per day. The corresponding figure for men with life change scores of 300 and above was 9.9. Those with intermediate life change scores had intermediate illness rates. Virtually all of the illnesses reported were relatively minor complaints that are not directly caused by stress. It is not a case of people getting sick if and only if they lead stressful lives. But when stress increases, so does the likelihood of getting sick.

Dr. T. H. Holmes and his colleagues devised this scale of impacts to gauge the amount of stress associated with various life situations.

University of Washington Medical School

THE SOCIAL READJUSTMENT RATING SCALE

LIFE EVENT	IMPACT VALUE
1. Death of spouse	100
2. Divorce	73
3. Marital separation	65
4. Jail term	63
5. Death of close family member	63
6. Personal injury or illness	53
7. Marriage	50
8. Fired at work	47
9. Marital reconciliation	45
10. Retirement	45
11. Change in health of family member	44
12. Pregnancy	40
13. Sex difficulties	39
14. Gain of new family member	39
15. Business readjustment	39
16. Change in financial state	38
17. Death of close friend	37
18. Change to different line of work	36
19. Change in number of arguments with spouse	35
20. Mortgage over $10,000	31
21. Foreclosure of mortgage or loan	30
22. Change in responsibilities at work	29
23. Son or daughter leaving home	29
24. Trouble with in-laws	29
25. Outstanding personal achievement	28
26. Wife begin or stop work	26
27. Begin or end school	26
28. Change in living conditions	25
29. Revision of personal habits	24
30. Trouble with boss	23
31. Change in work hours or conditions	20
32. Change in residence	20
33. Change in schools	20
34. Change in recreation	19
35. Change in church activities	19
36. Change in social activities	18
37. Mortgage or loan less than $10,000	17
38. Change in sleeping habits	16
39. Change in number of family get-togethers	15
40. Change in eating habits	15
41. Vacation	13
42. Christmas	12
43. Minor violations of the law	11

THE AUTONOMIC NERVOUS SYSTEM

The autonomic nervous system controls the internal organs of the body. Without our awareness or active involvement, it regulates the state of the heart, the glands, and the involuntary muscles. It consists of two complementary branches: the sympathetic nervous system and the parasympathetic nervous system. The sympathetic nervous system coordinates the "fight or flight" response to emergency situations: the heart beats faster, blood flow to the muscles and limbs increases, the bronchial tubes of the lungs dilate, and so on. The parasympathetic nervous system acts as an antagonist, or opponent, to the sympathetic nervous system. While the sympathetic nervous system increases heart rate, the parasympathetic branch decreases heart rate. When all goes well, these two branches of the autonomic nervous system act together to coordinate the complex bodily reactions of our emotional lives. However, when inappropriate reactions occur, psychosomatic disorders may develop.

If we think in evolutionary terms of our ancestors who lived in caves, reactions of the sympathetic nervous system to an emergency are very useful: they prepare the body to fight or to run away. In our complex technological society, their value is more questionable. For example, if a person is driving along a superhighway and a truck suddenly cuts him off, his sympathetic nervous system will inject adrenaline into the bloodstream, raise his blood pressure, and so on. But in our society, the driver does not have the opportunity to beat up the truck driver or to run away. He must suppress his anger and continue to drive. If he does this often enough, he may end up with high blood pressure.

COMMON PSYCHOSOMATIC DISORDERS

Psychosomatic problems occur most commonly in the circulatory system, the gastrointestinal tract, the respiratory system, the skin, and the endocrine system. Sometimes, symptoms can occur in several parts of the body at once.

Circulatory problems. High blood pressure is a circulatory problem that can be caused by physical problems, or it may be caused by psychological stress.

Migraine headaches are another psychosomatic problem involving the cardiovascular system. A typical migraine attack consists of two phases: the arteries in the scalp first constrict (decrease their diameter) and then dilate (increase their diameter). The results of these blood vessel spasms include nausea and painful headaches that may last for days.

Respiratory problems. The major psychosomatic disorder of the respiratory system is asthma. Asthma attacks may be caused by allergies, emotional upset, or both. In an asthma attack, the diameter of the bronchi (tubes that circulate air in the lungs) is decreased. As a result, a person cannot get enough air, pants, wheezes, and experiences a feeling of suffocation.

Gastrointestinal problems. Anyone who has ever had an upset stomach before a final exam knows that the gastrointestinal system responds to psychological stress. In addition to being the most familiar psychosomatic disorders, gastrointestinal problems have been the most thoroughly investigated. The major such disorders are peptic ulcer and anorexia nervosa.

The stomach produces several acids to break down food in the process of digestion. The lining of the stomach and intestine ordinarily resists the mildly corrosive effects of these acid substances. But, in some persons, the stomach acids begin to eat away at the protective mucous lining, and inflammation in the walls of the stomach—a peptic ulcer—occurs. An ulcer victim can easily experience nausea and shooting pains. If the ulcer perforates the stomach lining, serious internal bleeding may result.

The term anorexia refers to a loss of appetite: anorexia nervosa is a psychosomatic illness, mainly afflicting females between the ages of 16 and 20, in which self-inflicted starvation leads to dramatic weight loss, chronic invalidism, and even death.

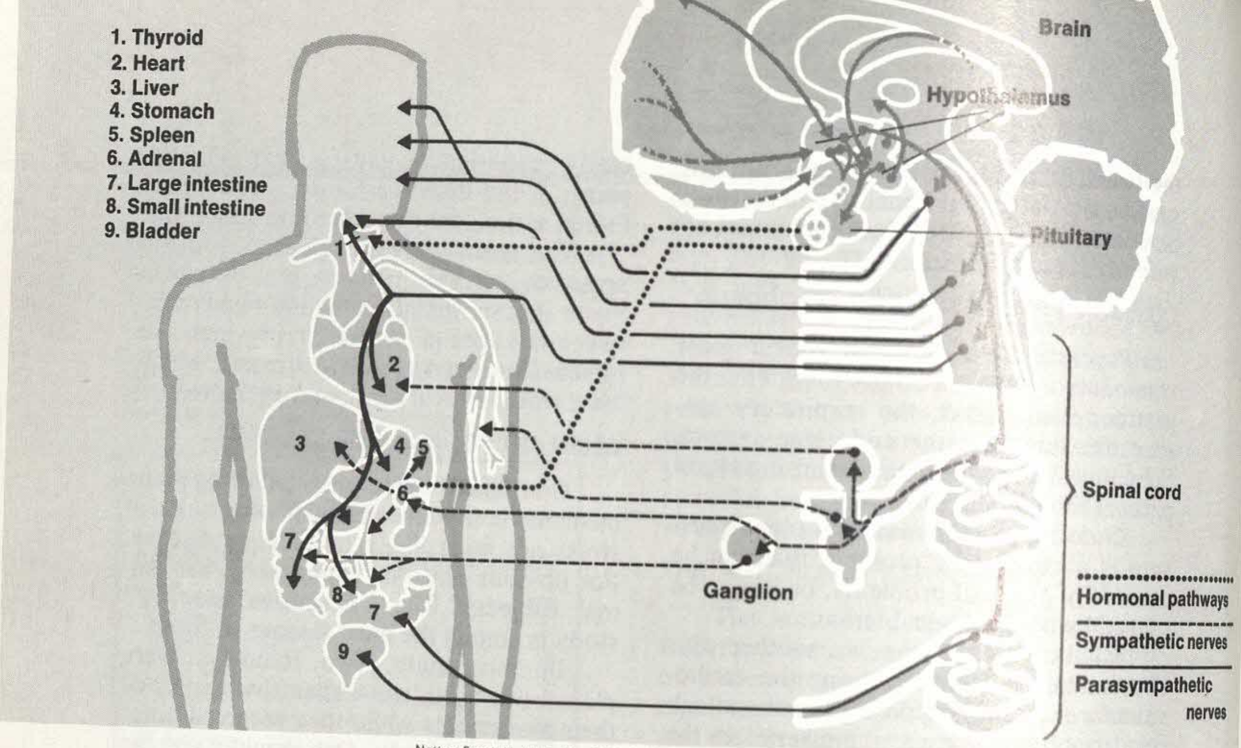
WHEN DO PEOPLE GET ULCERS?

One line of research in psychosomatic medicine is to determine just what kinds of stress are most likely to produce disease. For obvious reasons, experiments use animal subjects. The "executive monkey" study is among the most famous of these.

In this study, two monkeys were placed side by side in a chair that restricted their movements while they received occasional electric shocks. One monkey was the "executive." If he pressed a bar at exactly the right times, he could avoid the electrical shocks for both monkeys. Thus, both monkeys were exposed to identical physical stress. But the executive monkey was subjected to far greater psychological stress since only he had control over the situation. The executive had to remain constantly on the alert deciding whether or not to press the bar. In all the pairs studied, the executive monkeys developed stomach ulcers and their companions did not.

Later research with other species and other situations has made it clear that the relationship is somewhat more complicated than this may seem to imply. It is not simply that decision making causes ulcers; the specific kind of decision making is critical. Two important factors are: the number of coping responses the animal or person must make (the executive monkeys pressed the bar almost continuously); and the amount of feedback the responses produce (the monkeys had difficulty learning which bar presses in fact avoided shocks).

A related study indicated that assembly-line work can cause stress and ill health. Many such workers must make skilled judgments quickly and often. In addition, such work is monotonous and repetitive, and there is no feedback.



Netter, Frank H., M.D., *The CIBA Collection of Medical Illustrations*. The CIBA Pharmaceutical Company © 1972. All Rights Reserved

When the brain receives stress messages, it signals other parts of the nervous system. The alarmed body rallies to answer the stress situation. Adrenaline flows into the bloodstream; the pituitary and its hormones are activated, and other endocrine glands begin producing hormones. This triggers faster breathing and heartbeat rates, tensed muscles, and numerous other reactions. The body is now ready to act in self-defense. When social restraints prevent such action, the result is an internal physical imbalance that can ultimately lead to sickness.

WHICH PEOPLE GET ULCERS?

Imagine three executives holding similarly stressful jobs in the same company. One may develop ulcers, another high blood pressure, while the third may be perfectly healthy. What causes a person to develop a specific psychosomatic disorder?

At first, many physicians believed that different disorders were associated with different personality types. The classic ulcer patient, for example, was described as a highly competitive, hard-driving person who was hiding his dependency. The asthmatic was believed to be more openly dependent. High blood pressure was said to result from the suppression of anger. While there is some evidence of a relation between suppressed anger and high blood pressure, in general, it does not seem to be the case that a specific disease goes with a specific personality type.

On the other hand, there is evidence that each of us carries around an inherited tendency, or predisposition, to develop specific psychosomatic disorders. A baby is not born with a peptic ulcer, but rather with a "weak stomach." If that child is subjected to great stress, an ulcer will sometimes develop.

It has been shown that people are born with quite different levels of pepsinogen, which is one of the stomach acids. Individuals with high pepsinogen levels are far more likely to develop ulcers than are those with less pepsinogen.

TREATMENT

The treatment of psychosomatic disorders, like the diseases themselves, includes both mind and body. Physical symptoms must be treated medically. But such efforts only relieve the symptoms. Any real cure must involve treatment of the underlying cause. In some cases, this may involve psychotherapy. In other cases, the only cure is for the individual to stop leading such a stressful life.

Dan McCoy/Rainbow

Biofeedback therapy is often aimed at changing habitual reactions to stress. Here a subject listens to signals that tell him how he is responding to training.

BIOFEEDBACK

by Bette Runck

Around the turn of the century, a psychologist named J. H. Bair trained several young men to wiggle their ears. Now, this was no idle prank devised by the professor to endear himself to students. Bair was trying to understand how a person develops voluntary control over muscle movement.

This was Bair's procedure: First, the men gave themselves a very mild shock by pressing a key that was wired to stimulating electrodes attached to their ears. The shock jolted their ears into contracting (the ears, in other words, wiggled). Next, the men tried to move their ears without electrical help. By clenching their jaws and knitting their brows they found they could make their ears move, too. They could detect this faint sensation—normally lost amid the noisy muscles of cheek, chin, and brow—because they remembered how electrically induced ear contractions felt. They kept practicing, concentrating their attention on the sensation in their ears. Slowly they learned to dispense with the jaw-clenching and brow-knitting until finally they had perfected the rare, if useless, skill of wiggling their ears.

Modern biofeedback training is a product of knowledge gained in experiments such as Bair's. And it has much in common with his techniques. Like ear-wiggling, skills learned in a biofeedback clinic involve functions that people usually do not control voluntarily or may not even be aware of. Biofeedback is used, for example, to help patients regulate blood pressure and circulation or control tight, spastic, or paralyzed muscles. In biofeedback training, a machine or electronic device monitors these responses, then amplifies, records, and feeds them back to the patient. The biofeedback machine acts as a kind of sixth sense, allowing the person to "see" or "hear" activity inside the body. Then, using a variety of maneuvers that are already voluntary, the patient may learn to control the formerly involuntary response, just as Bair's subjects used brow-knitting to learn ear-wiggling.

Bair's experiment demonstrated that a person must first sense a response before being able to control it. For centuries, people have known, without realizing that they knew, that feedback is necessary to learn a skill. In gymnasiums, homes, fields, and shops, they monitored their own performances—attended to the feedback—while learning complex skills. It was only in Bair's time, however, that scientists learned that feedback was necessary to control physiological responses. Two of Bair's contemporaries, British scientists F. W. Mott and C. S. Sherrington, demonstrated that certain nerves feed back information that the brain uses to help the body function properly. When they severed these "afferent" nerves in a monkey's forearm, they found that the monkey could no longer use the limb voluntarily.

ALTERING BIOLOGICAL SYSTEMS

It was not until the mid-20th century that the full importance of feedback was recognized. Then, specialists in the new discipline of cybernetics began to study mechanical and human *systems*. They demonstrated that information about a system's past performance—that is, feedback—enhances the accuracy and precision of future performances. In the late 1950's and early 1960's, scientists in several different fields began using the feedback principle to try to alter biological systems. Working independently, they conducted pioneering experiments that foreshadowed biofeedback's diverse uses today.

Specialists in rehabilitation medicine had long depended on a machine, the electromyograph (EMG), to detect muscle activity. They used the EMG to measure damage to muscles resulting from stroke, disease, or accidents. In the early 1960s, they went one step further and started teaching their patients to regain at least partial control of damaged muscles, with the EMG readings guiding the patients' progress. This application of biofeedback has proved to be one of the most successful.

Meanwhile, researchers studying the brain began using feedback of brain waves, as measured by an electroencephalograph (EEG). They tried to teach their subjects to produce a particular brain-wave pattern, called "alpha," because they believed it was associated with an alert but relaxed state of mind. This use of biofeedback stirred great excitement because the alpha state was thought to constitute an altered state of consciousness. However, practical applications have proved disappointing.

At other research centers, investigators were studying the capacity of human subjects to control the autonomic nervous system. This is the part of the nervous system that controls normally "involuntary" functions such as heart rate and blood pressure. Researchers were trying to learn whether rewards and punishments could be used to teach people to regulate autonomic processes. This type of research led directly to the use of biofeedback for the control of blood pressure, heart rate, and disorders of circulation.

By 1970, the scientists working in separate disciplines had come to recognize similarities in their approaches and joined together to form the Biofeedback Research Society, which was later to become the Biofeedback Society of America. The word *biofeedback* reflects the field's connection to cybernetics, the study of the control of systems—in this case, biological systems.

HOW BIOFEEDBACK WORKS

Unfortunately, the connection with cybernetics sometimes has led people to believe that their bodies can be regulated with as much accuracy and precision as a machine can. The body, however, is far more intricate and finely tuned than any machine. Moment by moment, it regulates itself with feedback through mechanisms so complex that scientists have only recently begun to appreciate how little we understand about what goes on under our own skins.

Biofeedback is a relatively clumsy attempt to mimic or enhance these sophisticated capabilities of the body. But it is itself a much more complex procedure than it may appear to be. It works through several different mechanisms. Sometimes patients learn new skills much as Bair's subjects learned to wiggle their ears. At other times biofeedback is little more than a shortcut to relaxation.

Most scientists believe that relaxation is a key component in biofeedback treatment of many disorders, particularly those brought on or made worse by stress. High blood pressure and some kinds of headache are examples of this type of illness. Stress ofen produces strong emotions, which arouse certain physical responses. Many of these responses are controlled by the sympathetic nervous system, the network of nerve tissues that helps prepare the body to meet emergencies by "flight or fight"—by running away or by fighting the source of trouble.

The typical pattern of response to emergencies probably emerged during the time when all humans faced primarily physical threats. Although the "threats" we now live with are seldom physical, the body reacts as if they were: The pupils dilate to let in more light. Sweat pours out, reducing the chance of skin cuts. Blood vessels near the skin contract to reduce bleeding, while those in the brain and muscles dilate to increase the oxygen supply. The gastrointestinal tract, including the stomach and intestines, slows down to reduce the energy expended in the process of digestion. The heart beats faster, and blood pressure rises.

Normally, people calm down when a stressful event is over, especially if they have done something to cope with it. For instance, imagine your own reactions if you're walking down a dark street and hear someone running toward you. You get scared. Your body prepares you to ward off an attacker or run fast enough to get away. When you do escape, you gradually relax.

If you get angry at your boss, it's a different matter. Your body prepares to fight. But since you want to keep your job, you try to ignore the angry feelings. Similarly, if on the way home you get stalled in traffic, there's nothing you can do to get away. These situations can literally make you sick. Your body has prepared for action, but you cannot act.

Individuals differ in the way they respond to stress. In some, one function, such as blood pressure, becomes more active while others remain normal. Many experts believe that these individual physical responses to stress can become habitual. When the body is repeatedly aroused, one or more functions may become permanently overactive. Actual damage to bodily tissues may eventually result.

Biofeedback is often aimed at changing habitual reactions to stress that can cause pain or disease. Many clinicians believe that some of their patients and clients have forgotten how to relax. Feedback of physical responses such as skin temperature and muscle tension can help patients recognize a relaxed state. It gives them the information they need to know how well they are doing. The feedback signal may also act as a kind of reward for reducing tension.

BIOFEEDBACK IN PRACTICE

Biofeedback is widely used today by specialists in several different fields. It is usually offered in addition to other treatments. Sometimes physicians send their patients to special biofeedback clinics. More commonly, physicians, psychologists, and other specialists take extra training in biofeedback so that they can practice it themselves. Although biofeedback is used to treat a wide variety of disorders, it is not equally effective for all of them.

Movement Disorders. Rehabilitation of patients suffering from neuromuscular disorders or the aftermath of accidents and stroke is perhaps the most successful application of biofeedback to date. Depending on the disorder, biofeedback techniques are used to inhibit muscular spasm, activate neuromuscular cells, or relax muscles.

Many stroke victims suffering from hemiplegia, or paralysis of one side of the body, have been helped dramatically by biofeedback. Their treatment usually involves a program of physical therapy, plus biofeedback from the affected limbs. For them, as for many other patients with neuromuscular damage, just knowing that activity is still present in the damaged muscles can be very encouraging. But stroke victims, like many kinds of patients treated with biofeedback, vary markedly in their response. The time needed to produce a desirable outcome from biofeedback training also varies from patient to patient.

Headaches. Two very common types of headaches—migraine and tension—are often treated with biofeedback. Overactivity in the sympathetic nervous system, part of the autonomic nervous system, may be involved in both migraine (vascular) and tension headaches. The mechanisms that cause the pain are quite complex, but regardless of the causes, biofeedback treatment for both types of headache is probably most successful when it induces relaxation.

Migraine patients may be treated with several forms of biofeedback, but most commonly they are taught a formal relaxation technique. In addition, they learn to warm their hands just as Raynaud's patients do. For some reason not yet understood, warming the hands often causes migraine headaches to subside. This combination of relaxation and hand-warming has led to improvement in migraine patients, but relaxation training alone has also helped. Scientists are still trying to sort out whether and when the biofeedback training is needed.

The same can be said for the usual biofeedback treatment for tension headaches, which involves feedback of muscle tension. Relaxation exercises are almost always part of the treatment procedure. Feedback of muscle tension from the head and neck is used to guide the patient's attempts to relax.

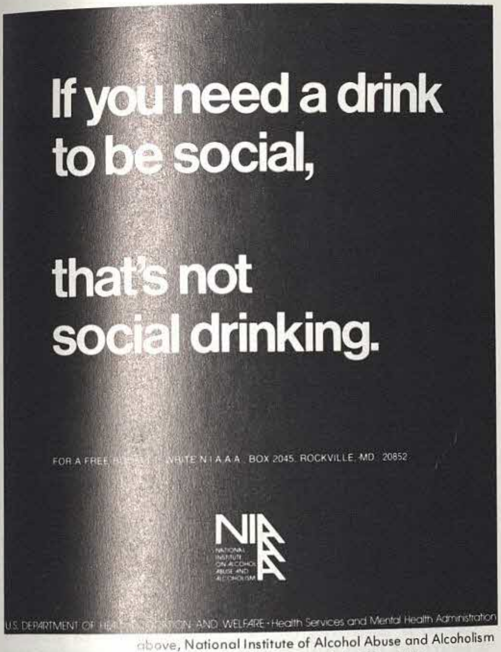
High Blood Pressure. Among the most hoped-for, yet still elusive, successes in biofeedback is in the treatment of high blood pressure. This condition, also known as hypertension, afflicts an estimated 15 to 20 of every 100 Americans. It can be dangerous—leading, for example, to kidney damage—or it can be fatal when it results in stroke. Although medications exist that control it, they produce troublesome side effects. For that and other reasons, patients neglect to take them. Biofeedback is seen as a promising alternative.

Several biofeedback procedures have been used to treat hypertension. Commonly, they involve teaching patients formal relaxation or meditation techniques. In addition, patients may be allowed to see some representation of their changing blood pressure. This feedback may help them to recognize how it feels to relax and to be in a state where their blood pressure is not elevated.

Epilepsy. The one use of brain-wave biofeedback that has produced promising results is in the treatment of epilepsy, a disorder of the central nervous system. The seizures characteristic of epilepsy are associated with abnormalities in the brain's electrical activity. Experimental biofeedback treatments have attempted to regulate brain activity and thereby reduce seizures.

About half of the patients who have undergone this type of training have been able to reduce their seizures substantially. Some have simultaneously cut down on required medication as well. However, since a few patients have experienced an increase in seizures after biofeedback, the treatment is still considered experimental. Investigators are trying to determine which patients benefit and to refine the techniques used for all of them.

Other Disorders. Biofeedback has been used for a wide range of other disorders. Some are primarily conditions involving pain—dental disorders, such as painful tension of the mouth, face, and neck, are common examples. For these conditions, biofeedback is used primarily as a technique to help patients learn to relax. Low blood pressure, asthma, sexual disorders, hyperactivity, learning disabilities, and stuttering have all been treated with biofeedback, as have a variety of other disorders. Only further research will establish the full value of these applications of biofeedback.



If you need a drink
to be social,

that's not
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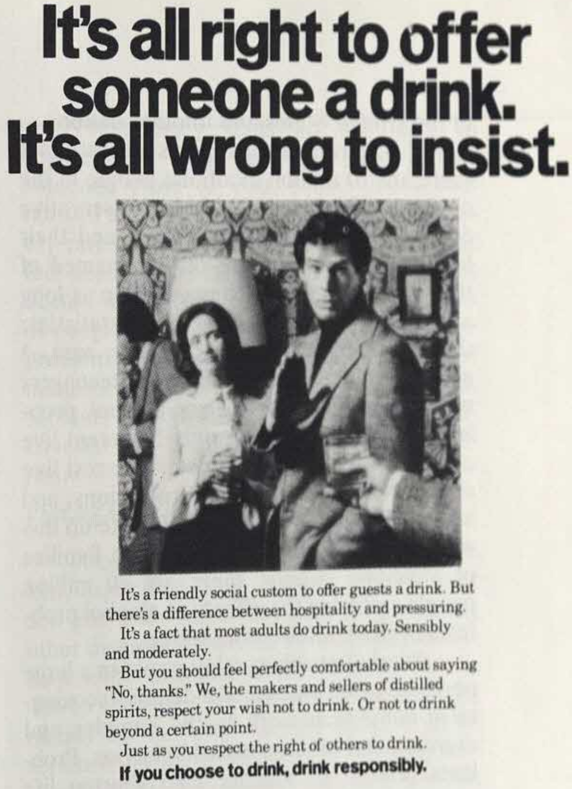
above, National Institute of Alcohol Abuse and Alcoholism
right, Distilled Spirits Council of the United States

Knowledge about alcohol and its effects is an important first step toward combating alcoholism. Above: cover of a free, informative booklet on alcohol abuse. Right: a poster emphasizing reasonable drinking habits.



It's all right to offer
someone a drink.
It's all wrong to insist.

It's a friendly social custom to offer guests a drink. But there's a difference between hospitality and pressuring.

It's a fact that most adults do drink today. Sensibly and moderately.

But you should feel perfectly comfortable about saying "No, thanks." We, the makers and sellers of distilled spirits, respect your wish not to drink. Or not to drink beyond a certain point.

Just as you respect the right of others to drink.

If you choose to drink, drink responsibly.

ALCOHOLISM

by Morris Chafetz, M.D.

Alcoholism is like lightning. We see and experience it, we are familiar with its presence and think we know it. But in fact we don't.

What do we mean by alcoholism? The United Nations World Health Organization (WHO) defines alcoholism as a chronic illness that shows up as a disorder of behavior. Usually alcoholic people, according to the WHO, repeatedly use alcohol as more than the usual accompaniment to eating or beyond the ordinary social customs of the community. This use interferes with the alcoholic person's health, ability to work, or ability to function in society.

My definition is a bit broader than that of the WHO. I think you have an alcohol problem (or alcoholism at the very earliest stage) when you spend a great deal of time thinking of or actually drinking; when you get drunk (overdosing with alcohol) frequently; when you get in trouble with work, family, or the law as a result of drinking; when you have accidents or get physically sick often from drinking; or when you become a very different person with alcohol than you are without it.

There are many other definitions, but these two generally cover most of the points people talk about when they consider alcoholism. A big question is whether or not alcoholism is a disease. As a physician, I do not believe it is a disease, although I know alcoholic people are sick, not bad, and that they are suffering from a serious state of illness. Whether it is called a disease or an illness is not terribly important as long as we recognize that alcoholic people are sick and need help.

NUMBER ONE DRUG PROBLEM

Alcoholism is a most common problem throughout much of the world. It is, in fact, far and away the number one drug problem in the United States and in other nations.

U.S. government reports indicate that there are 10 million alcoholic people in the country. That is probably a conservative estimate, since alcoholic people and their families and friends are often ashamed of the condition and try to cover it up as long as they can. Here are some of the statistics: there are approximately 6 million men, 3 million women, and 1 million teenagers who have signs of serious alcohol problems. Of the 10 million, only 5 percent live on skid row and are derelicts. The rest live and work in communities, professions, and socioeconomic groupings that make up this whole country. If you include the families of alcoholic people, there are 40 million people suffering the effects of alcohol problems in the United States alone.

Alcohol problems play a role in a large percentage of automobile deaths, accidental at-home or at-work deaths, suicides, and murders and other criminal behavior. Problems related to alcohol also shorten life expectancy by 10 to 12 years.

MOST LIKELY CANDIDATES

It is fair to say that everyone in the United States, and in many other parts of the world, will have someone among their family, friends, or close community who has an alcohol problem of some degree of seriousness. In the United States, people most likely to develop alcohol problems are persons who have alcoholism in the family, who live in certain parts of the country, who have certain occupations, or who have certain ethnic backgrounds. For example, 70 percent of the patients in the alcoholic clinics of the country report alcoholism in their family or in someone who was close to them while they were growing up. People who live in the Northeast, mid-Atlantic states, or Pacific West, and who are urbanized are more likely to develop alcoholism than people who live in the rural Midwest or South.

Advertising and media people, legislators, doctors, lawyers, and other professionals, and house painters are more likely to develop serious alcohol problems. Also, certain heritages makes you more vulnerable. The Russians, Scandinavians, Irish, and French have a larger number of alcoholism problems than do the Chinese, Italians, Jews, or Spanish. But remember, these factors are not guarantees or threats. Alcoholism can happen to anyone, anywhere.

NO SINGLE CAUSE

There is no single cause of alcoholism, just as there does not seem to be one kind of alcoholism. There are thousands of different types of alcohol problems and, naturally, there are thousands of causes. Some people think that alcoholism is inherited since it runs in families. The evidence to support a theory of heredity is not very strong, and many of us scientists believe that alcoholism runs in families because it is a learned behavior. By learned behavior we mean that young people learn how to use and misuse alcohol by watching the people around them. Almost all studies show that alcoholic parents tend to produce alcoholic young people, that heavy-drinking parents produce young who tend to drink heavily, that moderate drinkers produce moderate drinkers, and that abstainers produce children who tend to abstain.

Oher scientists believe that there is a biochemical defect in alcoholic people that does not permit them to handle alcohol in usual or normal ways. However, there is no good evidence to support this theory. As with the question of whether alcoholism is a disease or illness, searching for a biochemical defect is, I think, missing the point. No one can separate in any of us which part is inherited, biochemical, physical, psychological, or cultural. All of us have all these factors mixed up and blended into the persons that we are.

AN EASILY AVAILABLE DRUG

I have purposely left out all the many, many physical, psychological, and cultural theories about alcoholism and its cause because they are academic, technical, and repetitive. But it is important to remember what is known about this remarkable, accessible, and available drug. Alcohol is a depressant drug, not a stimulant. It is a depressant drug because with increasing doses it puts to sleep various parts of the brain and nervous system—to a point where, given large enough doses, sleep will become death.

People who drink think that alcohol is a stimulant because it seems to make them feel freer, have more energy, be less tired, and have fewer inhibitions than they had before they took alcohol. The feelings are accurate but the common reason given is not. The drinker feels stimulated and less tired and inhibited because, with social drinking, alcohol depresses, or puts to sleep, those parts of the brain that would normally signal us we were tired or uptight. Without these messages, or guardians over control, we talk, behave, and feel free—which is why alcohol is so popular a drug.

Alcohol also works fast, since a part of it quickly gets into the blood and to the brain without needing to be digested, as do other substances we consume. The amount of alcohol we take, how fast we drink, what food we have in our stomach, with whom and where we drink, how we feel physically and emotionally when we drink, and what we expect and our society will tolerate—all these will determine how alcohol is going to affect us. These are some of the reasons that the same amount of alcohol taken at different times can cause totally different responses.

EARLY SIGNS OF A PROBLEM

We need now to become aware of the early signs of alcohol problems. One of the first is that a person notices that he or she is very often thinking about or looking forward to taking alcohol. It becomes something special in life instead of just a small thing that is part of some other activity. A second sign is getting drunk often—even when you do not intend to. I believe that if you get drunk more than four times in one year you may well be on the road to a serious alcohol problem. I would be concerned if I did my drinking mainly when I was alone, or when I was overcome by problems or unhappiness. Alcohol is no problem solver. And certainly, if you behave as you never would, or do things you never would, without alcohol, you have a problem.

These early signs do not have to frighten you since they can save you or someone close to you. Most illnesses—if noticed and treated early—have high recovery rates. No one needs to be ashamed or feel second rate because of alcoholism. It occurs in all families and among all types of people. The only shame is ignoring the problem and thereby destroying the lives of millions of people who could be helped. Millions and millions of people have recovered and are recovering from alcoholism.

FAR-REACHING EFFECTS

Alcoholism can be a devastating problem, especially since it often is seen with and plays an important role in producing other diseases. The liver is an organ that is commonly affected by alcoholism. This is due to the fact that alcohol is metabolized mainly by the liver. About 10 percent of seriously ill alcoholic people develop *cirrhosis* of the liver. Cirrhosis is a serious disease in which the liver becomes knobby-looking due to scarring that has taken place. The person loses parts of the liver necessary for metabolism, and this in time can cause liver failure and death.

The stomach and intestines are also directly affected by alcohol problems. *Gastritis*—a red, inflamed, and disturbed stomach, is common in alcoholics, and this, in turn, may lead to the formation of stomach ulcers. Intestinal ulcers may also develop. The risk of cancer of the mouth, throat, and esophagus is also increased with heavy alcohol intake. A U.S. government study reported that heavy smokers who do not drink or heavy drinkers who do not smoke are two and a half times more likely to get cancer of the mouth, throat, and esophagus than are nonheavy smokers or drinkers. And if the person is both a heavy drinker and a heavy smoker, then his or her risk of getting these cancers jumps to 15 times the risks of the nonheavy smoker or drinker.

Muscles are also affected by alcoholism. Some heavy drinkers show considerable loss of muscle tissue in their arms and legs and even a softness in heart muscles.

The pancreas, an organ that secretes insulin to metabolize sugar, is also often damaged by alcoholism. But the brain and nervous system are where particularly horrible damage shows up with severe alcoholism.

BRAIN AND NERVOUS SYSTEM DAMAGE

Alcoholic psychosis is seen in many patients who inhabit mental hospitals. There is disagreement as to whether the psychosis is due to the toxic effects of alcohol itself or whether there already existed in people so affected a strong tendency to psychosis, which the heavy use of alcohol brings out.

Another frightening situation seen in alcoholism is a blackout phenomenon in which the person has a total memory loss. These people cannot recall what activities they engaged in or how they behaved when they were under the influence of alcohol.

Some people develop what is called *alcoholic paranoia*. People with this illness are suspicious, jealous, and accusatory. They often are disturbed in interpreting events in their surroundings, and they can develop panic emotional states.

Wernicke's syndrome is a disease found in alcoholic people who also have nutritional deficiencies, usually of the vitamin B group. They become delirious, confused, scared, have trouble walking, and lose their memory. More severe forms end up as *Korsakoff's syndrome,* a disorder in which the brain becomes damaged, producing disorientation as to time and place and weakness and tingling in the arms and legs because the nerves that go to these areas are affected.

Besides producing these severe illnesses, heavy drinking affects the progress of other conditions. People with alcohol problems do not recover as well from infectious diseases, and they seem to get more colds and pneumonia than do other people. They also bruise easily.

WITHDRAWAL—THE D.T.s

A very serious physiological change brought about by alcoholism is *delirium tremens,* or the D.T.s. This usually occurs after prolonged, heavy drinking and is a withdrawal event consequent to becoming physiologically addicted to alcohol. One does not need to totally stop drinking to develop the D.T.s. It can result from a sudden dropping of the blood alcohol level or from an injury or infection. The delirium is usually preceded by restlessness, irritability, trembling, a hatred of food, and an inability to sleep, with terrifying dreams when short periods of sleep do occur. The person is terrified and soon begins to see things: insects, snakes, and other animals from which the person cannot escape. The person becomes confused, excited, and agitated, with a great deal of physical moving about. It is hard to gain the person's attention.

This serious withdrawal state can end in death, but with good nursing care and the correct kind of medication, sleep is produced and the patient recovers. Untreated, the patient can go through extreme discomforts for three to ten days until he collapses from exhaustion, develops pneumonia, or dies from heart failure.

DANGEROUS COMBINATIONS

Still another and common effect of heavy drinking is unexpected death that can occur when alcohol is taken with other drugs, such as sleeping pills, antimotion pills, or antihistamines. Small doses of any of these, when combined with alcohol, tend to produce unpredictable, bizzare effects. All of us would be better advised not to take alcohol when taking other drugs.

Psychologically, people under heavy doses of alcohol are under anesthesia. It is a good rule to remember that anything a person does that requires full mental alertness is better done when not under the influence of alcohol.

A VERY TREATABLE ILLNESS

Alcoholism is a very treatable illness. This has been confirmed by a study done for the U.S. National Institute for Alcohol Abuse and Alcoholism that showed that 70 percent of the patients who attend government-supported treatment services recover.

The most common and usual treatment of alcoholic people is the psychological one. The ways this can be provided are quite varied. Psychiatrists use psychotherapy, one form of psychological treatment. The therapist and patient examine crucial emotional issues that affect the patient's view of the world, his responses, and behavior. It is an emotional experience that it is hoped leads to individual growth and the development of different ways of responding. Psychological treatment can be provided either individually or in a group setting. There is no uniform opinion as to which type is more effective.

Some people need what is known as *aversion therapy*. Aversion therapy is accomplished by giving the person some medicine that causes nausea and vomiting. This medicine is given at about the same time the person takes his favorite alcoholic drink so that an association of alcohol and sickness is created in the patient's mind. The person takes the alcohol and shortly after receives an injection of the vomit-producing medicine. These sessions are repeated every other day until a total of four to six are completed. Every six months a repeat treatment is administered. Electroshock techniques are also sometimes used in aversion therapy.

Another important form of treatment involves the use of the drug Antabuse, which was developed in Denmark in 1948. Antabuse causes an abnormal physiological reaction to alcohol. If a person taking Antabuse takes alcohol, he or she will, a few minutes later, feel a rush of heat, turn lobster red, feel a tightening in the neck, begin to cough and develop difficulty in breathing. Thirty minutes later the person becomes nauseated, pale, and scared, and begins to vomit. The effect usually ends with the person falling into a deep sleep. All people find this experience frightening and uncomfortable. The major drawback of Antabuse is that it must be taken every day to be effective. Most doctors find it helpful in combination with other forms of treatment.

EMOTIONAL SUPPORT IS VITAL

All people who treat alcoholics know that how you behave toward the alcoholic person at the first meeting is most important. The therapist has to reach out actively and be supportive because people with alcohol problems are depressed and expect to be rejected. Once the initial distrust of the patient toward helpers, society, and themselves is removed, treatment can be carried out.

One form of psychological-spiritual help to alcoholic people is the great self-help organization called Alcoholics Anonymous (AA). This loosely organized voluntary fellowship is well known worldwide. It was begun in Ohio in 1934 by an alcoholic stockbroker and an alcoholic physician and dramatically illustrates the ability of one person to help another recover from an alcohol problem. Its goal is sobriety achieved with help provided by the fellowship of fellow sufferers. Beyond its life-saving aid to thousands of alcoholic people, it's great impact has been to point out to noninterested

Alcoholics Anonymous is a self-help organization that emphasizes group assistance in facing the individual's drinking problem.

Alcoholics Anonymous

professionals that alcoholic persons can be helped. AA waged a battle and created interest while others hid behind attitudes of moralism and pessimism toward alcoholism and its effects. AA supplies comradeship: all members suffer the same disturbance. AA encourages self-examination and confession. It encourages dependency, since members take others under their wing and create a group identity.

There are other forms of treatment. There is behavior modification treatment, which is related to aversion therapy. There are also hypnotism, transcendental meditation, multivitamin therapy, lithium therapy, and so on. There are also special programs aimed at particular groups–for example, Indian alcoholism programs; drunk driver programs; programs for women and teenagers. All of these programs, with their special target thrust, depend on an approach tailored to the needs of the individual.

AN OUNCE OF PREVENTION

In spite of successes in treatment, it is important to keep one fact in mind: no condition of mankind has ever been controlled or advanced by treating the casualties alone. Prevention is an absolute necessity. Prevention of alcoholism requires: (1) an opportunity for earlier identification of people with alcohol problems than we now have, and (2) a change in the cultural attitude toward drinking to one that will make the choice of alcohol as a problem solver less likely.

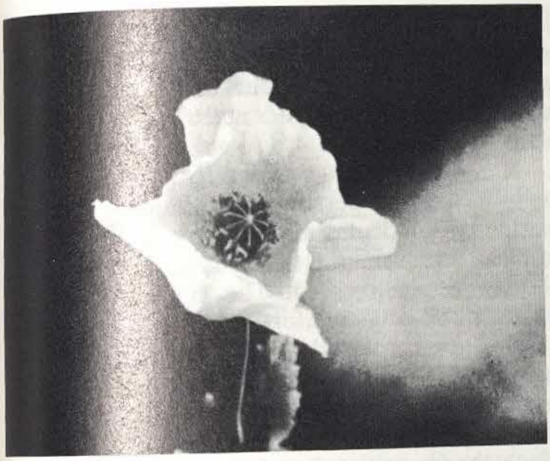
The first can be achieved by each person's learning what the limits are for safe drinking of alcohol. When a society sets up clear limits by which those people who use alcohol can know what is considered safe and considerate, then those persons whose responses are different will be more easily recognizable. Early diagnosis and treatment of alcohol problems means favorable outcome at low cost.

The second–a change in cultural attitude–can be achieved by teaching the safe way to drink to people who choose to drink. They need to know what alcohol is and how it works, how much better it is to sip than to gulp it, how important it is to have food in the stomach and be relaxed and comfortable while drinking, why alcohol should be consumed in group social settings, and why drunkenness should never be acceptable behavior. Most important, we all need to know that what we expect from alcohol and those who drink will in large measure determine how we will respond to the drinking of alcohol. It is not just an individual responsibility. It is a community responsibility. Prevention exercises can be accomplished by media messages, by mobilizing community and voluntary citizen groups, and by educational experiences.

RESEARCH

Finally, more research on alcoholism is needed. There are ongoing studies of the exact relation of alcohol misuse to cancer and heart disease, cirrhosis, gastritis, pancreatitis, and withdrawal reactions. There are studies to see if certain chemicals can quickly rid the body of heavy doses of alcohol and of how we can slow down the rate at which alcohol goes into the bloodstream. There is also research into how drunkenness and addiction develop. We need to know more about how alcohol affects driving. Knowledge that heavy drinking during pregnancy is not good for the developing baby has spurred research. We also need to know how the heavy consumption of alcohol can affect the hereditary material passed on to a child. We have to find the means to ensure that people can get treatment when they need it. We need to know more precisely what treatment is best for what person. Certainly we do not know enough about drinking binges or "blackouts."

We need to study the most effective ways of educating people about drugs and their safe and responsible use. Different groups need different prevention approaches, and we need to study what works best with which groups. But all of us must keep in mind as we examine the important issues of alcohol and alcoholism in our society that the problems are those of excesses and misuse, not the problem of the moderate use of alcohol.



Left: the opium poppy grows in Mexico and the Middle and Far East. Right: the leaf of the marijuana plant.

both photos, Bureau of Narcotics and Dangerous Drugs

DRUG ABUSE

by Donald B. Louria

A 13-year-old boy with a headache goes to the medicine cabinet for the third time for aspirin. He is a drug abuser, because he is dosing himself without real need or professional advice. The majority of legal drugs used now and then for minor illnesses without medical prescription are probably not necessary. But people will continue to take them as long as people believe that almost any sickness can be treated with a capsule, a tablet, or a spoonful of medicine.

In this article we are not concerned with such minor drug abuse. We turn our attention instead to those drugs whose misuse, beyond any true medical need, leads to serious problems. These drugs affect primarily one's brain or mind and behavior. They usually have effects on the rest of the body as well. The drugs in question may or may not cause physical dependence, or *addiction*, but many persons do become habituated to their use.

The unprescribed taking of certain "mental drugs"—heroin, marijuana, LSD, and others—is prohibited by law in many places. The mere possession of them may send the bearer or user to jail for many years. Furthermore, heroin users frequently commit crimes to support their habit financially. Other drug takers engage in criminal acts under the influence of drugs.

However, many medical drugs may be legally bought without prescription. Then there are the primarily nonmedicinal legal drugs, represented by tobacco, which contains nicotine, and certain beverages, containing ethyl, or grain, alcohol. These drugs are also greatly abused by the public.

Some drugs may grant release from bodily disease or pain. But certain other drugs affect the nervous system in different ways, often producing a variety of pleasurable feelings: a mood of joy—a so-called "high"; extreme activity; drowsiness or sleep; or even pleasurable visions or hallucinations.

Such mind-affecting drugs—*psychoactive agents*—are often a great boon to psychiatry for the treatment of mental and nervous diseases, and to medical research.

They are dispensed only under a doctor's guidance. Some, in fact, are not generally available.

Some psychoactive drugs may cause addiction. Addiction is the body's continued need for drugs because of their physiological effects after they are first taken. Heroin is a good example. If the body does not get the necessary additional doses of an addictive drug, distressing and sometimes serious illness is the result. Even if a drug does not cause addiction, it frequently becomes a psychological habit with the abuser. He or she has difficulty living without the drug.

What happens all too often to a confirmed drug taker, however, is the need for ever-larger doses as his body comes to tolerate a drug. Continued heavy doses of some psychoactive drugs may damage the mind or body permanently. Overdoses of heroin or similar drugs may lead to death.

A drug victim may take his doses in a number of ways: by mouth (orally); by smoking, in pipes or cigarettes; by sniffing the drug as vapor or powder; or by injecting it into the skin, muscles, or veins. Injection into a vein–mainlining–is usually the most direct, potent means of drug administration. The results are quick and dramatic.

TYPES OF DRUGS

A drug may be a pure chemical or, more often, a natural or artificial mixture of products. Although drugs have almost innumerable effects on us, for the purposes of this article we are interested in the ways they affect our nervous systems.

Psychoactive drugs are classified by the ways in which they influence the user. *Depressants* lower a person's activities, slowing him down and sometimes causing sleep. *Stimulants* have the very opposite effect. They make a person able to work or play for hours or even days without rest or sleep. *Hallucinogens* produce hallucinations in the taker. *Euphoriants* cause a good feeling, or high.

Depressants. The depressants include the *opiates*–derivatives of the opium poppy and similar but man-made drugs–such as heroin, Demerol, morphine, and methadone. Among the depressants we also include *barbiturates*, or sleeping pills; methaqualone; *tranquilizers* and *sedatives;* and alcohol.

Many of these drugs are called "downers." They slow a person down. Many are also addictive. Alcohol and opiates, such as morphine and Demerol, have an analgesic, or partly anesthetic, effect. They numb pain and other bodily discomforts.

Next to heroin, the synthetic opiate methadone is most responsible for addiction in the United States. Methadone is normally given as a substitute for heroin to reduce the severity of withdrawal symptoms in addicts undergoing treatment. Methadone, however, is now available as an illegal drug on the street and has become a major problem in its turn.

Once addiction to an opiate such as heroin is established, the user must take the drug every four to six hours. Otherwise, he goes through an abstinence, or *withdrawal*, syndrome that is characterized by nausea, vomiting, abdominal pains, sweating, and fever.

Withdrawal symptoms are more severe in barbiturate addiction. The victim becomes feverish and may suffer convulsions and coma or unconsciousness. He may even die.

Methaqualone, a legal drug, was originally intended to be a nonbarbiturate sleeping pill. But it is now being abused seriously. It produces a drunken high not unlike that caused by alcohol.

Alcohol itself is a depressant, although many people mistakenly regard it as a stimulant. In sufficient quantities it seriously attacks the nervous system, causing stupor and, in acute cases, death.

The depressants termed *tranquilizers* calm a person experiencing nervous tension or undergoing a serious crisis in life. They are also used to treat various mental illnesses. Some tranquilizers are legally available without prescription. Tranquilizers also cause drowsiness, which is a serious danger when the user is driving a car.

Stimulants. Drugs of this type make a person more active. They are therefore called "uppers," speeding up body reactions and giving a feeling of boundless energy. Actually, stimulants do not supply bodily energy, but cause a person to use energy faster. Stimulants are thus also called "pep pills."

Stimulants increase the heart rate and can cause very high blood pressure. These conditions occasionally damage the brain severely through hemorrhage. Irregular heartbeat is another symptom of stimulant abuse. Among the common stimulants are the *amphetamines,* or "speed," the drugs Preludin and Ritalin, and cocaine.

Part of the stimulant problem is the overdoses that are taken. Doctors prescribe dosages anywhere from 5 to 25 milligrams (1 milligram = 0.001 gram) three times a day for persons who need stimulants. But abusers take from 50 to 3,000 milligrams of amphetamines or Preludin daily, as pills or by injection. In recent years cocaine has become extraordinarily popular. It is sniffed or injected.

These giant intakes of stimulants have many undesirable side effects on the mind. The most common results are mistakes in judgment and violent acts committed from a feeling of being persecuted. This feeling is often characteristic of a mental disease known as *paranoia,* in which the patient believes that everybody is out to get him.

Whether prolonged stimulant overdoses cause permanent brain damage is uncertain. Medical opinion holds that most people recover from the effects of stimulant abuse over a period of weeks or months, sometimes in a year. But occasionally the victim is left with lasting injury to the brain.

Physical addiction to stimulants is rare, although sometimes extreme trembling and abdominal pain may occur after sudden withdrawal. Because of increasing bodily tolerance of these drugs, the user takes bigger doses until he or she becomes exhausted and gets very little of the desired effects.

Hallucinogens. These drugs, of which LSD is the most typical, are able to change the ways in which people sense and understand their surroundings. Sensations, especially of colors, become more intense, distorted, or surrealistic. Users say they "see" sounds or smells and "hear" sights. Ordinary objects seem to pulsate with life. There may be complete hallucinations.

Exactly how LSD acts on the mind is not really known at present. It seems to cause chemical changes in the brain and to bind itself to the nucleic acids. (Nucleic acids are natural compounds that bear the "blueprints" for the life activities of cells.)

Other hallucinogens include STP (which is amphetaminelike), DMT, mescaline (from the peyote cactus), psilocybin (from a mushroom), and PCP (phencyclidine), a veterinary anesthetic. Hallucinogens are usually swallowed but may also be injected. A DMT experience lasts two to four hours, whereas an LSD "trip" takes four to twelve hours. The effects of an STP dose may persist for days. Psilocybin is very similar to LSD in its results.

Much of the danger from LSD lies in the misunderstanding of the environment it causes. Although it does not happen as often as stories imply, people sometimes do jump out of windows, step into traffic, walk into fires, or drown in the ocean.

LSD may also, like the amphetamines, cause feelings of persecution, which can lead to aggressive or violent behavior. Other frequent side effects of LSD are mental abnormalities that require a doctor's or hospital treatment. How often such results occur is uncertain. But a seemingly normal person who takes LSD may become mentally ill, requiring hospital care for months or, rarely, years. Hallucinations may recur without more LSD. A "bad trip" or a "good trip" depends on an individual's state of mental health prior to taking LSD.

Euphoriants. Euphoriants are drugs that give a feeling of gaiety or elation. Sensations are enhanced and inhibitions are lowered. Marijuana and hashish are the chief drugs in this group. Hashish is simply a more concentrated form of marijuana. The two drugs may also cause light-headedness and giggling.

The precise way marijuana acts on the body and mind is not yet known. But it is clear that the reaction to marijuana also depends on other factors besides the chemistry of the drug. Of importance are the expectations of the user, the setting in which the drug is taken, other people who may be present, the user's personality, his emotional state, and the amount of the dose.

If an individual merely thinks he is smoking marijuana, but is really not, he frequently will describe a marijuanalike experience. Scientists have confirmed this by experiments with human subjects. Smokers were given either marijuana or an inert but marijuanalike substance. About two-thirds of those who smoked the substitute said they had experienced a mild to moderate marijuana high.

If a person feels content, the marijuana experience is likely to be pleasant. But should he be anxious, smoking the drug may cause a feeling of panic. If the smoker is really unhappy, marijuana may induce a sense of utter despair. However, few marijuana users undergo such effects.

The most important psychoactive ingredient in marijuana is a natural compound known as *tetrahydrocannabinol,* or THC. The average marijuana cigarette contains about one gram of marijuana, with a THC content of approximately 1 percent. But there is a great variation in the content of "joints," which consist of from 0.5 to 2.5 grams of marijuana, with THC ranging from 0.4 to 2.4 percent.

Thus, the amount of marijuana actually inhaled by a smoker may vary markedly. If enough THC is taken in a short time, an individual will experience the same kinds of hallucinations produced by LSD. The THC appears to bind to nucleic acids and may persist in the body for substantial periods.

It has been reported that marijuana produces liver diseases and brain damage as well as birth defects in the offspring of users. But none of these claims have been confirmed in man. The experiments and clinical observations have been incomplete, or poorly conducted, or have not been substantiated by other scientists.

Other experiments, however, clearly show that marijuana affects a person's judgment and reaction time adversely, especially when he or she drives a car. In some instances, the effects of marijuana smoking are similar to those produced by drinking alcoholic beverages. It has also been suggested that marijuana can suppress sperm production and cause breast enlargement in young men.

NICOTINE AND ALCOHOL

The use of tobacco, which contains nicotine, and of alcoholic drinks is almost entirely legal in the United States and many other countries. There are more legal restrictions on the use of alcohol than on the use of tobacco. Both drugs may be directly harmful to the health or may cause injuries to the users or even innocent bystanders.

Tobacco. Millions of people spend millions of dollars annually on cigarettes in spite of the apparent harm cigarettes cause to the mouth, throat, lungs, heart, and circulatory system. Many scientists believe that the nicotine and tars in tobacco are far more dangerous than certain illegal drugs.

According to one scientist, cigarette tobacco costs 300,000 American lives a year, with an annual economic loss of some $25 billion. At least 80,000 of these deaths are due to lung cancer, which may have been caused by smoking.

A somewhat arbitrary and controversial definition of cigarette abuse is based on public-health data. For normally healthy persons, the smoking of fewer than ten cigarettes daily carries only a slightly greater risk of lung cancer than that for nonsmokers. With more than ten "smokes" a day, there is a substantial cancer risk, which increases steadily as more cigarettes are consumed daily.

Alcohol. Like tobacco, alcoholic drinks are also potentially or extremely dangerous. In a recent year alcohol cost the lives of 25,000 to 50,000 U.S. citizens with some $25 billion in economic loss. Some 10 million alcoholics in the United States are abusing alcohol. So are millions of others who are not alcoholics but who suffer from excessive intake of alcoholic beverages.

Not only is alcohol in large doses destructive to mind and body, it also causes many accidents on account of intoxication.

TABLE OF DRUG ABUSE

Types of Drugs	Popular Names	How Taken	Symptoms and Effects
Depressants: morphine, heroin, Demerol, codeine, and other opium-like drugs (narcotics); barbiturates; tranquilizers; Methaqualone; alcohol	Snow, junk, smack (heroin); cough medicine (codeine); sleeping pills, dolls (barbiturates); downers (tranquilizers); drink, booze (alcohol)	Injection (morphine, heroin); pills (barbiturates, tranquilizers, Methaqualone); liquid (alcohol, codeine)	Drowsiness, stupor; sleep; slow breathing and pulse; pupils of eyes small; drunkenness (alcohol, Methaqualone); possible severe withdrawal symptoms—coma, death
Stimulants: amphetamines; methamphetamines; Preludin; Ritalin; cocaine	Pep pills, uppers (amphetamines); speed, meth (methamphetamines); coke, snow, lady (cocaine)	Pills or injection; cocaine may be chewed as leaves. Cocaine powder may be sniffed	Extreme activity; sleeplessness; restlessness; aggressive feelings; violence; high pulse rate and blood pressure; with extreme doses, collapse, even death
Hallucinogens: LSD; STP; DMT; mescalin, psilocybin, PCP	Acid (LSD); cactus, peyote (mescalin); mushroom (psilocybin); angel dust (PCP)	Swallowed as pills, capsules or liquids; DMT injected or smoked	Hallucinations; odd language and behavior
Euphoriants: marijuana; hashish (tetrahydrocannabinol in both)	Pot, weed, grass, joints, reefers (marijuana); hash (hashish)	Usually smoked, in cigarettes and pipes	Happy behavior ("high"); hallucinations with heavy doses; carelessness; loss of attention and ambition; panic; possible antisocial acts; possible body harm
Glue (variety of chemicals in glues and similar material often used in assembling model planes and other toys)		Sniffed or inhaled from tubes or other containers	Drunken, possibly violent behavior; great body damage; possible suffocation
Nicotine (in tobacco)	Smoke; weed; snuff; cut plug	Usually smoked; also sniffed (snuff); sometimes chewed (cut plug)	Widespread effects; raised heartbeat and blood pressure; nausea; with long use, cancer, lung disease, heart trouble

When alcohol is taken along with other drugs, the results may be fatal. One of the worst combinations is a barbiturate and whiskey. The enhancing effect of drugs when they are taken together is called *synergy*. Another example of a synergic pair is alcohol and methaqualone.

WHY DRUGS ARE ABUSED

Curiosity is one of the strongest reasons why people try drugs. But it is not the only one. Pleasure is another, and a very strong, motive for abusing drugs. Obviously, few people would take drugs outside of medical treatment without some kick they get from them. Illegal, mind-altering drugs are one of the chief sources of thrills in a pleasure-seeking society, perhaps made even more thrilling by the very fact that they are illegal.

But taking a drug alone is seldom any fun. Many people like to do it with their companions to share their highs and dreams. Therefore the influence of friends and associates—one's so-called peers—is very important in one's getting started on a drug habit. In fact, many studies have shown that the influence of the peer group is by far the most important factor in sending a person down the road of drug abuse. It is stronger than all the other factors combined.

There are other influences that shape a person's interest in drugs. Broken homes account for much drug abuse among youngsters. Also, those children whose parents abuse tranquilizers, sedatives, alcohol, and cigarettes are more likely to use illegal drugs by a factor of two or three times over those whose parents do not smoke or drink or pop pills. If, at ages 10 to 14, a boy or girl experiments with tobacco, he or she is more likely later to become involved with marijuana than is a child who has not experimented.

However, there are drug users who do not fit any of the above patterns. Any young person of whatever background may become part of the drug scene, at least experimentally. This is especially true of marijuaua smokers.

There is also substantial evidence that many youngsters use drugs out of sheer boredom, while others do so to escape adolescent mental pain. This is often the case even when they say they do it for kicks.

THE MARIJUANA CONTROVERSY

Today a bitter controversy rages, particularly in the United States, over the alleged benefits and dangers of marijuana. There is still uncertainty about many effects of the drug. Many medical scientists believe that the following statements about marijuana may be safely advanced:

(1) Most people who smoke marijuana in average amounts experience either pleasure or nothing at all.

(2) For some persons, marijuana can have unpleasant results, including panic, depression, and other psychiatric abnormalities.

(3) Some chronic marijuana smokers may be harmed psychologically, losing their ambitions and goals in life. But if they stop smoking the drug, they may resume their normal behavior and attitudes.

Marijuana, then, is by no means entirely safe. But neither is it a terrible drug that drives its victims to serious crime. Why don't we, therefore, simply legalize marijuana? According to medical opinion, there are at least three important reasons for caution in doing so.

First, as shown before, marijuana may be dangerous to the user as well as to innocent bystanders, particularly if a user drives a car when under the influence of the drug.

Second, there is convincing evidence that some marijuana smokers escalate to using more hazardous drugs, which include hashish, cocaine, and hallucinogens. This is more likely to happen the more often a person smokes marijuana.

In a New Jersey Medical School study, individuals rarely using marijuana had only a 4 percent chance of graduating to more dangerous drugs. Those who smoked marijuana at least once a month showed about a 9 percent chance of going on to more powerful substances. For weekly users of marijuana, the likelihood rose to 22 percent; for twice-a-week smokers, to 44 percent. In other studies, a daily marijuana smoker ran the risk of probably experimenting with more dangerous drugs in the 65 to 85 percent range.

The studies described here do not show any necessary relationship between marijuana use and other drugs. Neither do they indicate that smoking marijuana forces one into taking more dangerous drugs. However, the more marijuana one smokes, the more likely that he or she will be in the minority of users who will get involved with hallucinogens.

And, finally, third, there is the question of how many legal drugs we want in our society. Of the current three legal, nonmedical drugs–the caffeine in coffee, tea, and some soft drinks; the nicotine in tobacco; and the alcohol, in wine, whiskey, and beer –the last two are considered very hazardous. Do we want to add marijuana, with its known dangers, to tobacco and drink as permissible drugs?

REHABILITATION OF DRUG USERS

Once an individual becomes part of the drug scene, his rehabilitation is often very difficult. For example, today there are no adequate rehabilitation centers or programs for LSD users, marijuana smokers, amphetamine takers, or cocaine abusers.

For some drug victims, psychological counseling or psychiatric therapy, on an individual or group basis, may be of help. In addition, there are a few therapeutic communities that deal with the ravages of the drugs mentioned above. But their effectiveness has not been proved as yet.

Methadone maintenance. For opiate addicts, there are better opportunities for treatment. One of the most popular and well-publicized methods is methadone maintenance. As we stated earlier, methadone is a habit-forming substitute for heroin. It is usually taken orally once a day, ending the addict's craving for heroin and preventing him from experiencing the symptoms of withdrawal from heroin.

In well-run programs, approximately 80 percent of the enrolled addicts remain for at least one year. Their criminal behavior falls off markedly, and many addicts get jobs. At the end of four or five years, 60 to 65 percent have remained in the methadone program. Most of the former addicts adjust to society in satisfactory ways.

The addicts who accept methadone maintenance are volunteers and so are at least reasonably well motivated for cure. They frequently are in their late 20's or in their 30's.

Therapeutic communities. In contrast to methadone maintenance, therapeutic communities strictly forbid all drugs. The addict under treatment lives in a rigidly run communal setting, where group discussions and encounters are the rule.

The addict is made to face himself and accept his faults. He is then helped by the group to adjust his personality and life to a completely drug-free existence. If the addict does not conform to the group's demands and rules, he is punished in various ways and made to look or feel uncomfortable or even ridiculous.

In most therapeutic communities, the addict remains a full-time resident for 12 to 18 months. The main problem with these communities is that their harsh tactics are difficult for many addicts to tolerate. Thus the dropout rate during the first three months of stay usually ranges from 50 to 80 percent of enrolled addicts.

Civil commitment. Some states, such as New York and California, have tried to compel treatment for addicts who commit crimes or who are signed into programs by their relatives. Most of the addicts receiving forced treatment are not motivated for cure, however. The results of civil commitment have so far been discouraging, despite the psychological therapy, educational improvement, and job training offered to those in the programs. For the most part civil commitment has been abandoned.

There are methods of treating or advising drug users other than those discussed above. They include religious groups and various counseling and guidance services, of which there are many. Religion, however, apparently does not appeal to most addicts. As for the other approaches, there is at present very little information about their success.

DRUGS AND THE LAW

In past years, jail sentences even for illegal possession of drugs have sometimes been extremely harsh. For example, a 23-year-old Vietnam veteran was sentenced to 120 years for selling a small amount of marijuana and LSD, and an addict who sold a small amount of heroin in Texas was sentenced to 1,500 years. In recent years there has been a striking change in societal and legal attitudes. Drug use is now often overlooked and possession of small amounts of even very dangerous drugs is frequently regarded as a minor offense.

Possession of large amounts of any illegal drug, especially agents such as heroin or cocaine, still results in potentially long prison sentences. Many people are in favor of more severe sentences, even for possession. Others feel that possession of currently illegal drugs should be decriminalized.

The laws must be very carefully designed so that the punishment fits the crime. Only intelligent and concerted action by the scientist, the physician, the governmental authority, the police, and the concerned citizen can put an end to drug abuse.

American Cancer Society

There is a definite link between smoking and certain types of cancer. Intensive campaigns against smoking have been under way since the link was proven.

SMOKING AND HEALTH

The use of tobacco has been with us for a long time, but it has not been until recently that the effect of smoking tobacco has been studied in depth. Tobacco was long thought to be harmless, and some confirmed smokers even looked to it as a soothing practice. Now there is very strong evidence that smoking is a hazard to health. Smoking irrates the throat and respiratory passages. It is sometimes linked to loss of appetite, nausea, shortness of breath, and irregularity of the heartbeat. But, even more important, smoking—particularly cigarette smoking—has been linked to chronic and often fatal diseases of the respiratory tract. Overwhelming statistical evidence shows that smokers are more likely to develop cancer of the lung, throat, tongue, and jaw than are non-smokers. They are also more likely to develop emphysema and bronchitis—two other serious respiratory diseases. The evidence is so conclusive that many nations have undertaken intensive public education campaigns to warn people of the dangers of smoking. In the United States this involves a statement on all cigarette packages: "The Surgeon General has determined that cigarette smoking is dangerous to your health."

HISTORY OF TOBACCO USE

Tobacco is the dried leaf of several species of *Nicotiana*, a genus of plants belonging to the potato family. Native to the northern part of South America, it was cultivated in various parts of the Americas before Columbus came to the New World. The word tobacco is derived from the Indian word *tabaco*, used for both the plant and the pipe in which it was smoked.

Columbus is said to have brought small amounts of tobacco to Spain from Cuba. We know that the plant was exported at an early date from the New World to Portugal. There it came to the attention of the French ambassador, Jean Nicot, who sent some seeds to France about 1560. Nicot gave his name to *Nicotiana*, the genus to which tobacco plants belong, and also to nicotine, the alkaloid found in tobacco.

Sir Francis Drake brought some tobacco from the New World to England in 1585. He told Sir Walter Raleigh that he had seen Indians exhaling smoke derived from burning tobacco leaves. To Sir Walter is due the honor—if it may be called that—of having made pipe smoking popular in England. The practice of tobacco smoking was adopted in many lands, but some people frowned upon it. Even after the practice had become established among men, every effort was made to keep women from adopting it. Until the twentieth century women who smoked were held to be either rustics or eccentrics. Today smoking is widespread among both men and women.

WHAT IS IN TOBACCO

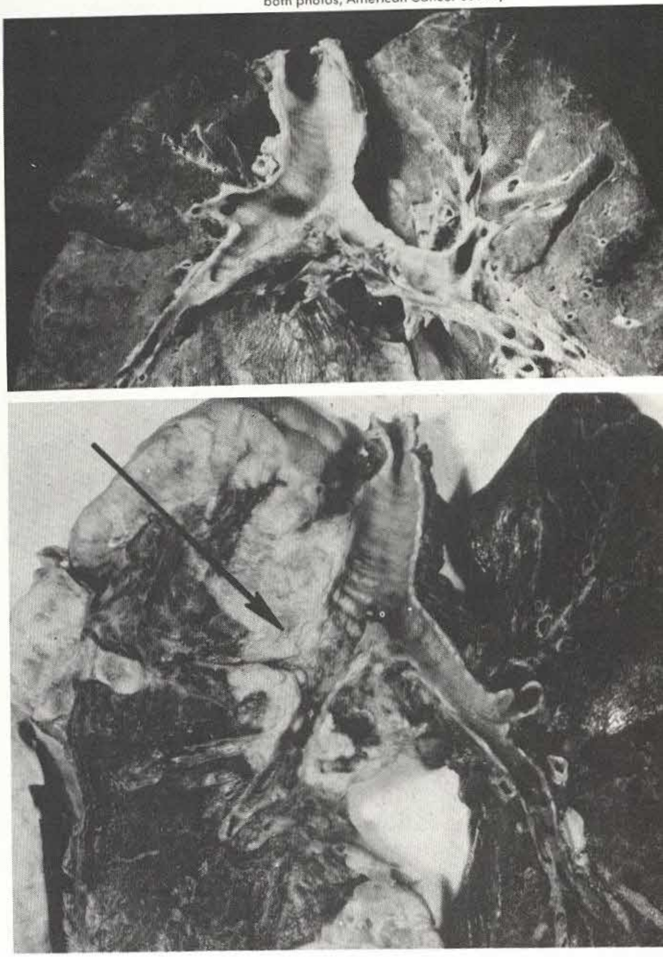
Tobacco can be smoked, chewed, and sniffed. Nicotine is released from tobacco during all of these processes. In the original leaf nicotine is bound to organic acids. It remains bound to these acids when the leaf is slowly dried. Besides nicotine, tobacco smoke contains pyridine compounds, ammonia, carbon dioxide, carbon monoxide, organic acids, ketones, and aldehydes. It also contains tobacco tar. All of these substances are irritating in varying degrees to the mucous membranes of the mouth and respiratory tract.

Apart from the tobacco tar contained in tobacco smoke, the effects of tobacco depend almost entirely upon its nicotine content. Nicotine is a clear liquid that becomes brownish after it is exposed to air. It is absorbed in the body from smoke that has passed through the lungs. Nicotine also passes into the tissues from the alimentary tract, if it has been mixed with saliva during smoking, snuffing, or chewing and has afterward been swallowed.

From five to fifteen per cent of the nicotine that is absorbed passes out of the body in the urine without having undergone any change. The rest is transformed in the body into simple compounds or into compounds related to nicotine and probably decomposes in the liver. If one inhales cigarette smoke deeply, the amount of nicotine absorbed and excreted in the urine is increased by this practice.

NICOTINE'S EFFECTS

Whether nicotine is introduced into the body by smoking or by injection, the effects on the brain and spinal cord are relatively simple. Small doses have a stimulating effect upon various centers in the medulla oblongata region of the brain. They affect the respiratory center in this area by reflex action. That is, they produce effects on other physiological processes that in turn affect the respiratory center in the brain. They act directly upon other centers that slow up the action of the heart, constrict the arteries, and cause vomiting. Small doses usually produce a mildly sedative, calming effect on the highest brain centers.



Top: lung from a non-smoker. Bottom: cancerous lung (arrow) from a heavy smoker.

both photos, American Cancer Society

Large doses depress the medulla centers. This condition is always dangerous and may prove fatal. The nicotine present in tobacco smoke could not possibly bring about such depression. The nicotine would have to be introduced into the system in some other way—for example, by being absorbed through the skin or by injection. When death takes place in such cases, it results not from paralysis of the heart but from arrested respiration. This is apparently brought about by the paralysis of the nerve endings which lie in the respiratory muscles.

Nicotine interferes with the formation of urine by acting on the pituitary gland. It causes this gland to release the antidiuretic hormone, which impedes the flow of urine. If a person drinks a large quantity of water and receives an injection of nicotine, he will retain much of the liquid for a time. The same effect would probably be brought about by smoking one or two strong cigars.

Nicotine acts upon various ganglia, or relay stations, of the nerves that make up the autonomic nervous system. These nerves bring about actions that are independent of our will. There are two sets of nerves in the system—sympathetic and parasympathetic—which produce opposite effects. The sympathetic nerves generally stimulate body activities; the parasympathetic nerves check them. Sometimes the roles of the nerves are reversed.

The ganglia of both sets of autonomic nerves leading to the heart are stimulated by nicotine. Generally the heartbeat rate first slows down and then speeds up. Under the effect of nicotine the blood pressure is raised. It is sometimes first lowered and then increased. Nicotine causes less blood to circulate in the skin. A distinct drop in skin temperature can be noted.

TOXICITY

In large doses, nicotine depresses all sympathetic and parasympathetic nerve relay stations. In this respect it acts like some drugs that are used to lower blood pressure levels. The margin of safety between a depressant dose of nicotine and a fatal dose is very narrow. This is one reason why nicotine is not used by physicians in the treatment of high blood pressure.

Fatal cases of nicotine poisoning were not rare when tobacco infusions, containing nicotine, were used as insecticides. This was because nicotine can be absorbed effectively through the skin. In nicotine poisoning, an excessive amount of saliva is produced. There are cold sweats and nausea. The blood pressure rises. The heartbeats are slow and irregular. Toward the end, the blood pressure falls rapidly. The pulse becomes weak. There are muscular twitches and tremors. These tremors often develop into convulsions. Respiration becomes increasingly labored. When it fails, the sufferer dies.

It is extremely difficult to treat nicotine poisoning. There is no specific antidote to counteract its effects, particularly its depressant effects. Nicotine tremors may be stopped by certain drugs. In extreme cases the sufferer's life may be saved by artificial respiration or by slow intravenous injections of drugs, which cause blood pressure to rise.

Some people—a minority of users of tobacco—are extremely sensitive to nicotine, even in the comparatively small amounts present in tobacco smoke. This is especially true of persons suffering from impairment of the blood circulation. For example, smoking aggravates the symptoms of Buerger's disease, in which the small blood vessels in the limbs are painfully constricted. The effect of smoking is to constrict the blood vessels still more. Patients suffering from Buerger's disease are generally chronic smokers. If they give up smoking, their condition improves. If they do not stop smoking, poor circulation can cause tissue death. Gangrene can set in and the affected area may have to be amputated.

In certain extreme cases, occurring generally among middle-aged people, a heavy smoker's vision may become fogged. If he continues to smoke excessively, he may even become temporarily blind. Normal vision is restored after the patient stops smoking.

Nicotine may increase hydrochloric acid secretions in the stomach. Physicians

Children often model their behavior on that of their parents. Thus a parent's smoking may influence a child to take up the habit.

American Cancer Society

believe that this results in aggravating peptic ulcers. Hence they advise patients suffering from this ailment not to smoke.

It seems likely that, in certain instances at least, there is a definite connection between smoking and coronary heart disease. Statistics have shown that death from this disease is twice as frequent among heavy cigarette smokers as it is among nonsmokers. Many doctors tell patients who have had attacks to stop smoking. Nicotine, of course, is by no means the sole cause of such attacks, but it is one of the most serious.

Most persons develop a tolerance for nicotine. When a novice has his first experience with strong tobacco, he is likely to become violently sick. He will be dizzy, pale; and nauseated; perhaps he will vomit. After the first trial, or first few trials, the unpleasant symptoms generally do not recur because tolerance to nicotine is acquired. When one or two milligrams are given by mouth to novices, they feel nausea. In inveterate smokers, from six to eight milligrams of pure nicotine are required to produce nausea. This tolerance masks the harm caused by nicotine.

Smoking becomes a habit that is extremely difficult for most smokers to break. Various factors contribute to the formation of the habit. As one authority put it, "the pleasure of smoking is partly due to the calming action of nicotine on the central nervous system, partly due to the smell and partly due to all the ritual associated with lighting up."

Early experiments showed that nicotine is involved in the formation of the habit. Certain heavy smokers gave up smoking and were injected with a little over a milligram of nicotine over a period of days or weeks. They reported that the hypodermic satisfied their craving for a smoke. Nonsmokers found the effect of the same dose of nicotine unpleasant. In some people the ritual part of smoking may be a very important factor in establishing the habit. When heavy smokers observe their customary smoking ritual, they may be content with denicotinized cigarettes as a substitute smoke. However, many notice a difference, due to the absence of nicotine.

IS NICOTINE ADDICTIVE?

Many researchers feel that nicotine is an addictive substance. The fact that some smokers and other tobacco users actively seek tobacco on a daily—if not hourly—basis seems to support that idea. Addiction to nicotine is certainly not the case in all tobacco users, but researchers believe that this is the case in some. This idea of nicotine as an addictive substance has not been accepted by many U.S. researchers, but it has been adopted by British scientists and has been incorporated into government policies concerning smoking in the United Kingdom. Among the complaints reported by people who have stopped smoking are nervousness, drowsiness, anxiety, lightheadedness, headaches, fatigue, irregularity of bowel movements, sweating, and cramps. Whether some or all of these are symptoms of withdrawal from an addicting substance is open to question.

SMOKING AND CANCER

Since the beginning of the twentieth century, it has been suspected that smoking may lead to cancer of the lung. At first cigar and pipe smoking were considered chiefly responsible. Evidence now indicates that cigarette smoking is chiefly responsible. The evidence is based on the following facts:

(1) There has been an increase in both cigarette consumption and cancer in recent years.

(2) There is a high proportion of heavy cigarette smokers among lung cancer patients.

(3) Cancer has been produced in experimental animals by applying material condensed from tobacco smoke.

Numerous investigators have shown the relationship between cigarette smoking and lung cancer. One of the first large-scale studies was undertaken by the American Cancer Society. The Society launched a research project based on a study of 190,134 white men between the ages of 50 and 69 inclusive. These would include heavy and light smokers of cigarettes, pipes, and cigars as well as nonsmokers. Their smoking habits or nonsmoking habits would be studied over a period of years. A careful record would be made of those who succumbed to lung cancer. The project was headed by Drs. E. Cuyler Hammond and Daniel Horn, director and vice director, respectively, of statistical research for the Society. Other doctors and 22,000 field workers co-operated in the project.

The first report on this study was published in *The Journal of the American Medical Association* for August 7, 1954. The records of 187,766 men had been successfully traced. Of these men, 167 had died of lung cancer. Of these, 143 had a history of regular cigarette smoking.

The researchers found that the death rate from all causes among cigarette smokers was definitely higher than it was for men who had never smoked or who had smoked only cigars or pipes.

Drs. Hammond and Horn drew the following conclusions:

(1) Lung cancer is rare among men who have never smoked.

(2) Lung cancer is an important cause of death among men smoking two or more packs of cigarettes a day.

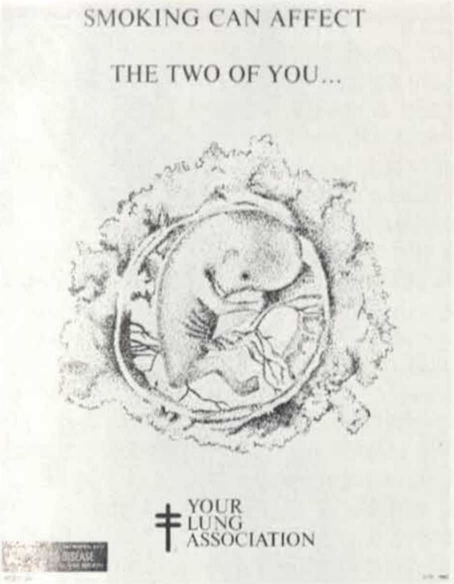
(3) The death rate from lung cancer increases with the amount of cigarette smoking.

(4) Pipe smoking seems to be associated with lung cancer but to a far less degree than cigarette smoking. There seems to be no connection between cigar smoking and lung cancer.

(5) In both urban and rural groups, the lung-cancer death rates are high in cigarette smokers and very low among men who had never smoked.

(6) Giving up cigarette smoking reduces the risk of lung cancer.

In a subsequent report Drs. Hammond and Horn confirmed their earlier findings concerning the relationship between cigarette smoking and the development of lung cancer. They noted also that cigarette smokers were particularly apt to develop cancer of the larynx, esophagus, and bladder, coronary artery disease, cirrhosis of the liver, influenza, pneumonia, and duodenal and gastric ulcers. They pointed out that nonsmokers can develop cancer (1) because they have inhaled tobacco smoke contributed by smokers or (2) because they have been affected by general air pollution. This may have been due to industrial fumes



American Lung Association

and soots, exhaust from gasoline and diesel engines, or fine dust from asphalt or bituminous road surfaces.

A somewhat similar survey was carried on in England by Drs. R. Doll and A. B. Hill. They examined the smoking habits of 40,000 British physicians and they noted the cases of cancer that developed among them. They came to much the same conclusions as Drs. Hammond and Horn.

Perhaps the most influential report in this field in recent years was that issued by the United States Public Health Service in January 1964. The report gave the results of a survey conducted by the President's Advisory Committee, which was headed by Dr. Luther L. Terry, Surgeon General of the Public Health Service.

The members of the Committee came to the conclusion that cigarette smoking definitely causes lung cancer and that the risk of developing the disease increases with the number of cigarettes smoked per day. They noted, too, that cigarette smoking is a contributing factor in deaths from coronary artery disease, bronchitis, and various other ailments. Apparently, they observed, cigar smoking and pipe smoking are far less harmful, though pipe smoking may lead to cancer of the lip. They pointed out that atmospheric pollution and industrial poisons contribute less to lung disease than does tobacco smoking.

Cigarette manufacturers do not concede that there is a definite connection between cigarette smoking and cancer of the lungs. They are, however, required by law to print the warning "The Surgeon General has determined that cigarette smoking is dangerous to your health."

SMOKING AND CHILDREN

The use of tobacco during pregnancy can affect the development of an unborn child – and nearly one third of all women of childbearing age smoke cigarettes. It has been shown that smoking mothers tend to have smaller babies than nonsmoking mothers. Babies born to smoking mothers run a greater risk of dying within the first year of life. Other studies have shown that smokers have a greater chance of miscarriage and of giving birth to children with congenital defects.

In experiments involving rhesus monkeys, nicotine introduced into the maternal bloodstream affects the blood pressure, heart rate, oxygen supply, and acid balance in unborn monkeys. Perhaps these are similar to the effects of smoking by human mothers. Carbon monoxide, a component of cigarette smoke, is also a hazard to the unborn child. In the blood, carbon monoxide competes with oxygen. This results in a decreased supply of oxygen to the fetal tissues and seriously affects development.

Studies of children whose mothers smoked during pregnancy indicate that these children have more chance of developing heart defects and cancer, or exhibiting certain neurological disorders. Some studies done in Great Britain also indicate that children whose mothers smoked during pregnancy lag in reading level and social adjustment level.

Another thought to consider is that children who come from families that have at least one smoking member are more likely to develop the habit themselves. Peer pressure from outside the home is also an important contributing factor.

ALLERGIES

by Howard G. Rapaport

Each year, about midsummer, millions of persons—children and adults alike—begin to show various significant symptoms. They sneeze, their eyes itch and become watery, and sometimes even breathing is difficult. They feel wretched for a month or two. Then the symptoms abate. These persons are suffering from attacks of hay fever—a prime example of what physicians would call an *allergy*.

To understand what allergies are, we must point out that when the normal equilibrium of the human body is threatened by an external agent, a sequence of automatic defense mechanisms moves into action. If the body becomes overheated, for example, it begins to perspire in order to cool itself. If it becomes too cold, it starts to shiver in an attempt to get warm. An allergy is also a response to an external agent. But in this case the response to this outside source is excessive and the reaction is neither normal nor desirable.

Over two thousand years ago, the ancient Greeks described what appear to have been allergic reactions. Many of the supposed lepers mentioned in the Bible may really have been suffering from an allergic skin disease, such as eczema. It is highly probable, indeed, that allergy and the allergic reaction are as old as man. Only in the twentieth century, however, has medical research been able to identify the specific nature of this type of disease and to start hunting for a cure for it.

There are literally hundreds of possible causes of allergy, and the reaction may express itself in the human body in many different ways. One person breaks out in hives when he eats strawberries. Another starts to sneeze in the presence of dogs or cats. A third reacts to ordinary house dust. Some people have asthmatic attacks when faced by an emotional crisis. Certain allergies are quite strange. For example, a bank teller had to change his job when it was discovered that he was allergic to money.

FDA

A woman is applying depillatory cream to her leg. Will she develop skin redness and burning? Allergies—some involving skin contact with particular substances—are quite common.

SUSCEPTIBILITY

The symptoms of allergy may first appear at any time from infancy to old age. They occur most often, however, before the age of twenty. Indeed, one of the major problems facing the doctor who treats allergies is to recognize the condition early enough so that he will be able to start treatment when it can do the most good. Many allergic reactions are mistaken for other, less serious, conditions, especially in the case of infants and young children. Parents often neglect to mention these reactions to their physician until they have recurred several times.

It has long been known that inheritance plays a significant part in allergy. A person who has two allergic parents or whose family has a history of allergy has up to ten times as much chance of developing an allergy as a person from a nonallergic family. Moreover, his symptoms will usually appear at an earlier age than would otherwise be the case.

However, persons with no trace of an

allergic inheritance may also develop allergies, and some members of an allergic family may be completely free of allergic illness during their entire lives. There is not always a direct relation between the type of allergy present in the parent and that which appears in the offspring. For example, a mother with asthma may have one asthmatic child, another who suffers from allergic skin disease but who is free of asthma, and a third who shows no signs of any allergy.

It is not the allergy itself, but rather a tendency or susceptibility to allergy, that is passed on from parent to child. A person may have a tendency to allergy and yet never experience a single moment of allergic illness. His system is prepared at all times to react violently to an allergic assault. He is fortunate enough, however, never to have come upon an allergic substance under conditions that would lead to a visible reaction.

TYPES OF ALLERGIES

The major types of allergy are hay fever (seasonal or perennial), asthma, and eczema, or allergic dermatitis (inflammation of the skin brought on by an allergy). Most allergists believe that persons who are plagued with continuous or frequently recurring colds have a form of allergy. Among the other conditions with a strong allergic basis are hives; contact dermatitis, which is caused by direct contact between the skin and the offending substance, such as poison ivy; pruritus, or severe localized itching; recurrent croup; canker sores; periodic vomiting; colic; repeated inflammation of the eyes; recurrent boils; chronic sinusitis; and recurrent headaches.

The form that allergy takes in the human body generally depends on the area under attack. If we examine allergic tissue under a microscope, we find the same reactions no matter from what part of the body the tissue was taken. These reactions include a weakening of the tiny blood vessels known as capillaries and a swelling of the tissues, due to an accumulation of fluid in and around the cells. Different parts of the body react differently to these changes, resulting in different types of allergies. The areas most likely to be attacked are the skin, which covers and protects the entire body, and the respiratory system, by means of which we take in the air we breathe and all the foreign matter that may be in it.

CAUSATIVE AGENTS

Exactly what causes an allergic reaction? As far as medical science has determined, foreign substances enter the body and find their way to the bloodstream. These foreign agents, called *antigens*, stimulate the production of a class of *antibodies* called Immunoglobulin E (Ig E) antibodies. There are thousands of different kinds of antibodies, each one produced to combat a specific type of antigen.

Upon their release from plasma cells, Ig E antibodies circulate to various parts of the body and attach themselves to *mast cells*, a class of cells that are located in parts of the body where foreign substances could enter, such as respiratory passages, skin surfaces, and the digestive tract. The process of attachment is called *sensitization*. Hundreds of thousands of Ig E antibodies may attach themselves to the surface of a single mast cell, waiting to interact with the particular antigen that originally caused their production.

Later, if the same kind of antigen enters the bloodstream again, it combines with the antibodies and the complex triggers a release of chemicals called *mediators* from the mast cells. More than 15 mediators with different functions have been identified. These mediators initiate a local inflammatory response.

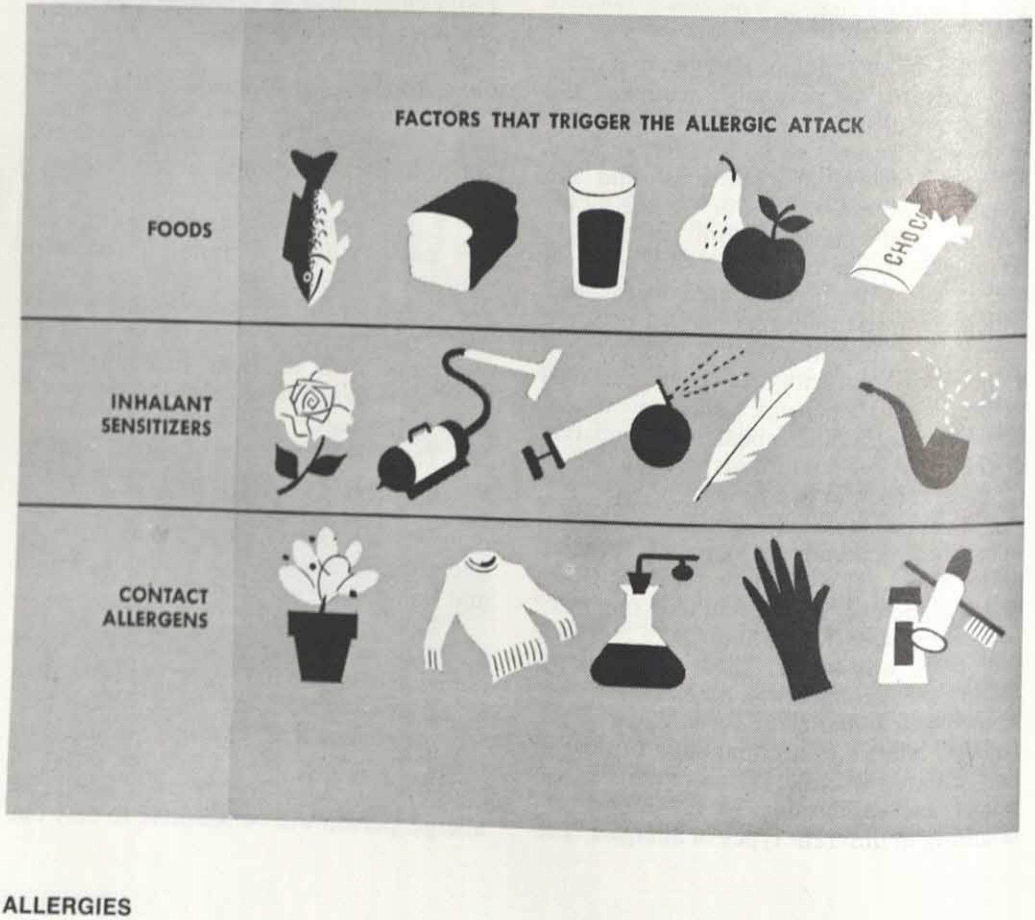
The exact symptoms of allergy depend on the effects of the mediators and in which part of the body the antigen–Ig E–mast cell combination exists. Three major types of allergenic substances are inhalants, foods, and skin-contact substances.

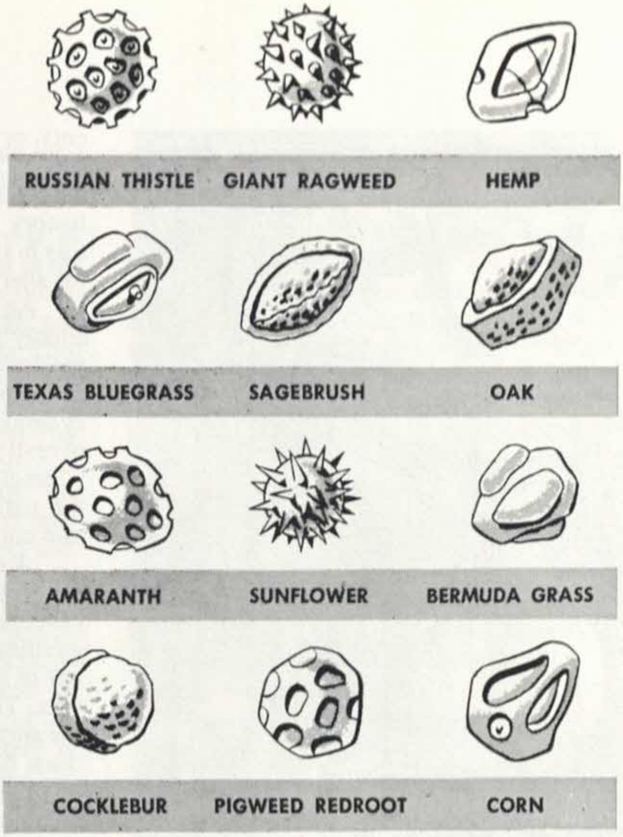
Inhalants. Inhalant materials are the major cause of allergic attacks. The most common of all are the pollen of plants such as ragweed, grass, and trees. These pollens are generally the cause of seasonal hay fever. They may also mark the onset of severe year-round symptoms. Usually the allergic person will be sensitive to only one type of pollen, but sometimes one type of seasonal allergy will lead to another. The most serious aspect of hay fever, as of frequently recurring colds, is that it will frequently lead to asthma if allowed to go untreated for any length of time. Asthma is a severe chronic condition, marked by difficulty in breathing. It can be crippling and is sometimes fatal.

Ordinary house dust, formed by the slow deterioration of many different materials in the home, is another important inhalant offender. The hair and dander of many animals are allergenic materials, as are feathers, molds, insect sprays, and vegetable fibers. Strong odors and fumes may bring about a severe attack of allergy in an allergic individual.

Foods and liquids. Food is a common source of allergic attacks. Reactions usually occur in children after eating or drinking the allergenic food and in adults after inhaling it as dust or fumes. However, there have also been instances of food allergy due to contact alone. Eggs, milk, nuts, wheat, fish, meats, chocolate, and many other standard foods are liable to produce an allergic reaction when eaten by themselves, or together with other allergenic foods, or as a minor ingredient in an otherwise harmless dish. The allergist, faced with a complex problem of food sensitivity, sometimes has to track down the offending substance much as a master detective ferrets out a criminal who has found a place of refuge in a city of a million persons.

Skin-contact substances. The best known cause of allergic reactions through direct contact is, of course, poison ivy, which will affect the skin of most persons violently even if they merely brush against the plant. But there are many other materials whose touch produces just as violent a reaction in sensitive individuals. Among





These dustlike pollens, highly magnified here, all produce allergic reactions in susceptible individuals. These pollens are nearly indestructible and can travel great distances.

these are other plants, cosmetics, hair dyes, clothing, plastics, metals, woods, chemicals, paints and varnishes, and jewelry.

Others. Drugs and medicinal products can cause severe allergic reactions either by injection or swallowing or through mere contact. A large number of persons treated with the antibiotic penicillin have developed an allergic sensitivity to it. This is also true of other antibiotics and of older drugs such as aspirin and the sulfas. Insect stings and bites, particularly those of the yellow jacket and other wasps and bees, have been known to cause violent allergic reactions.

These systemic (whole body), as opposed to local, reactions result when very large amounts of chemicals that affect the blood vessels enter the circulatory system and cause lowered blood pressure and constriction of the small air passages in the lungs. In severe cases, without medical intervention, death may occur within half an hour. In the United States, allergic sudden death, called *anaphylaxis,* may account for several thousand deaths a year.

Among the factors that sometimes result in allergic reactions are acute infection (by either bacteria or viruses), extreme changes in temperature, excessive activity, and emotional stress. The exact role of emotions in allergy still remains uncertain. A few investigators believe that it is very often a direct cause of allergy; many others hold that it often complicates the allergic reaction but rarely causes it.

DIAGNOSING ALLERGIES

As we have pointed out, the doctor who treats allergy must often play the part of a master detective, particularly when trying to determine whether or not an illness is actually allergic in nature, and—if it is—exactly what causes it. The first concern is usually the same as the patient's: the symptoms or signs of illness that brought him to see the doctor. Sudden spasms of sneezing and coughing, a running nose, and watery eyes—all point to hay fever, particularly if they have come on during a pollen season. But perhaps the patient simply has

Grant Heilman

Common foods, including some fruits and vegetables, can trigger an allergic reaction in some people. Usually, eating the food brings on the attack, but skin contact may also be involved.

a cold. Wheezing may mean asthma, or the beginning of pneumonia. Actually, most allergists feel that wheezing is almost always the same thing as asthma. Hives or eczema may be a sign of food allergy, sensitivity to animal hair, or a reaction to a nylon blouse. Slowly, with extreme care and attention to detail, the skilled allergist makes his way through the maze of vague hints and sometimes contradictory signs to the correct diagnosis. Perhaps the symptoms alone will reveal the answer. Often, however, they will indicate that further study is needed.

The previous medical history of the patient and his immediate family sometimes provides the key to a correct diagnosis of allergy. If the patient had frequent bouts of colic or diaper rash as a child, or if his parents or other close relatives have been treated for allergy, it is very likely that he is susceptible to allergy himself. A complete history may also indicate the specific factors in the patient's environment that cause his allergic attacks.

An important tool in the diagnosis of allergy is the *Allergic Index*, which allows the doctor to keep track of any reaction that might possibly be allergic in nature. Each symptom is given a specific weight in the overall allergic picture. When a certain total is reached, the physican can be sure that the patient has a significant major allergy and can adopt measures to control it.

A most important element in the diagnosis of allergy, after taking a history, is the process known as *skin-testing*. After he sterilizes the skin, the doctor makes a number of small, painless scratches in the forearm. They are just deep enough to break the surface of the skin but not so deep as to draw blood. A small amount of pollen, egg, or other material suspected of causing the allergic attack is then placed on a scratch and mixed with a solvent, applied with a medicine dropper. A different substance is rubbed into each scratch.

If the patient is allergic to one of the materials tested, a minor local reaction that looks like hives or a mosquito bite will usually appear on the site of the scratch within ten or twenty minutes. Perhaps allergy to several different substances will be indicated. The absence of a reaction does not mean that no allergy is present, but rather that other tests must be used to find it.

Another type of skin test, the *intradermal*, is sometimes used when scratch tests have not given positive results. In this method, a minute amount of the suspected material is injected directly into the skin of the patient, instead of just being rubbed into a scratch on the surface. The intradermal test will often indicate whether or not an allergy to a specific substance exists. However, since it may lead to severe reactions, it is not used so frequently.

If a contact allergy is suspected, a simple *patch test* may be performed. This involves placing a bit of the suspected substance (such as paint, soap, or a cosmetic) next to the skin and taping it in place for a day or two. A positive reaction almost always indicates allergic sensitivity.

In all types of skin tests, there is always a blank or *control test,* applied at the same time as the others. In this, the skin is scratched or punctured but no allergic material is introduced. The doctor can then determine whether the patient is allergic to the irritation caused by the scratching or injection, rather than to the test material.

Unfortunately, numerous factors may complicate a program of skin testing. For one thing, while a positive reaction may indicate a definite allergy to the test substance, it does not prove that a specific substance is the cause of the allergic condition present in the patient. Also, a positive skin reaction may only indicate a previous sensitivity or potential future sensitivity to the substance being tested. The results of any program of skin testing, therefore, must be related to the disease symptoms, to the previous history of the patient, and to any other pertinent conditions.

TREATMENT

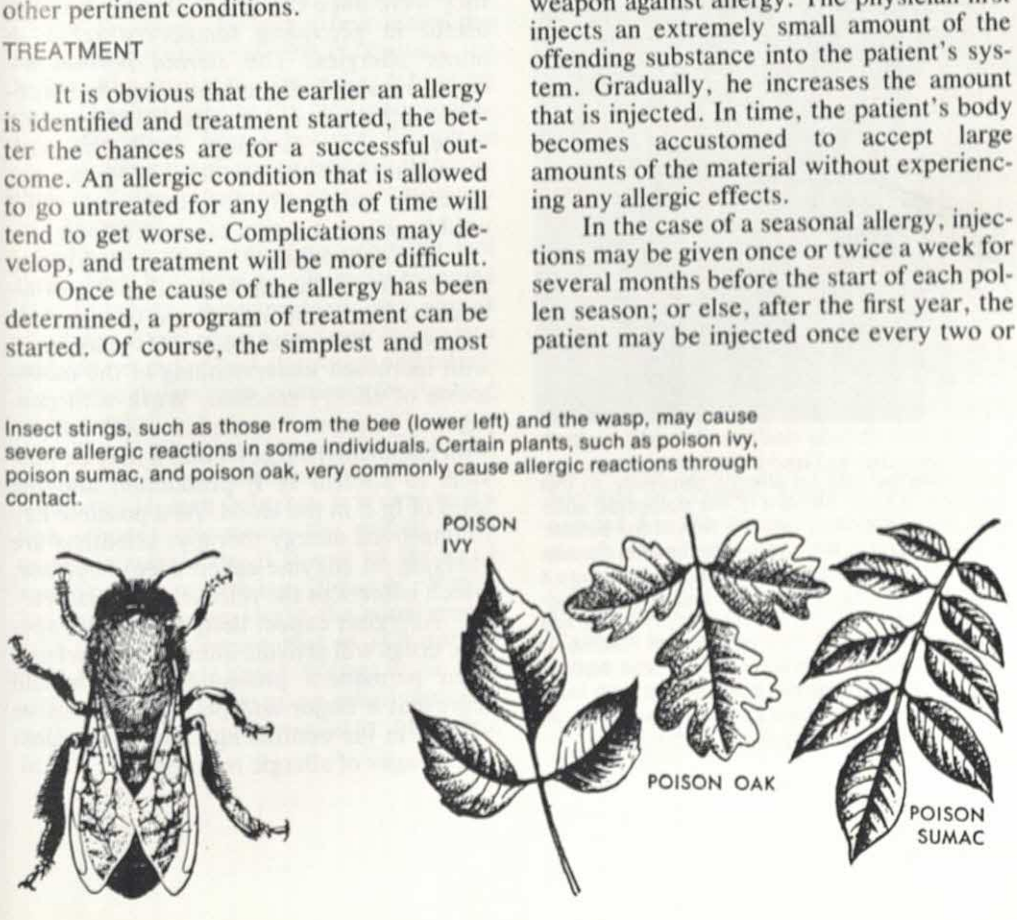
It is obvious that the earlier an allergy is identified and treatment started, the better the chances are for a successful outcome. An allergic condition that is allowed to go untreated for any length of time will tend to get worse. Complications may develop, and treatment will be more difficult.

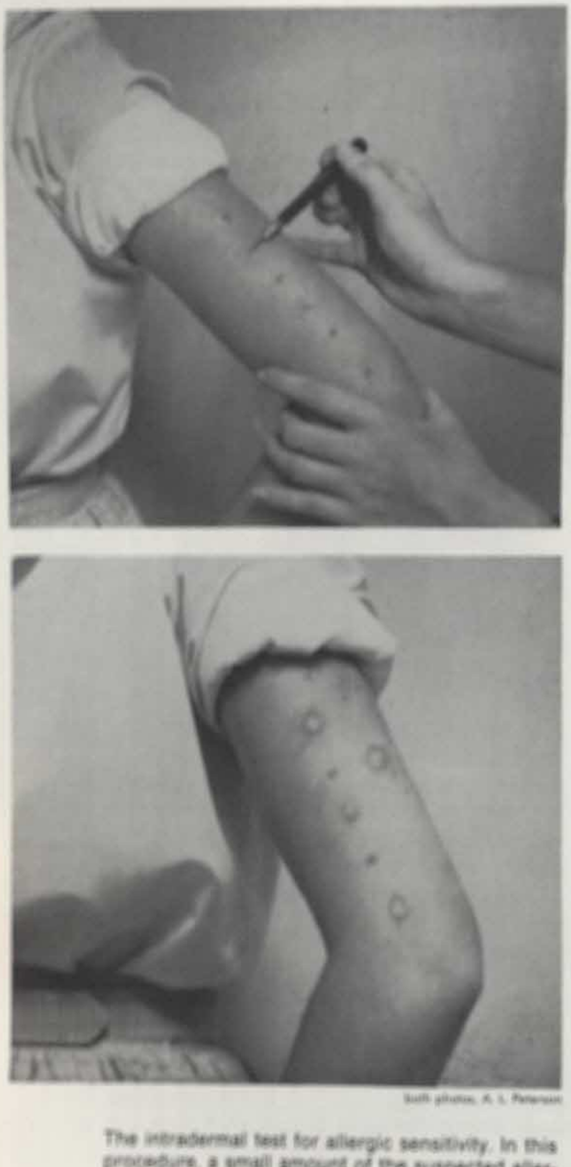
Once the cause of the allergy has been determined, a program of treatment can be started. Of course, the simplest and most effective treatment would be to avoid all future contact with the offending substance. Unfortunately, this is not always possible. It is relatively easy, for example, to keep from swallowing aspirin or touching the poison ivy plant, but how does one go about avoiding house dust, or ragweed pollen during the height of the pollen season? It is not always feasible to move to a place where the offending pollen is not found. When allergy to a particular food has been demonstrated, it is best to eliminate the allergenic food from the patient's diet. We can safely substitute many foods, prepared especially for allergic children, for allergenic items, and at the same time maintain a healthy and varied diet. Of course, only a doctor is qualified to decide on an adequate diet when any basic food must be forbidden.

Hyposensitization. When contact with the allergenic material cannot be avoided, the patient's system must be trained to live with it. This is done by means of *hyposensitization,* which is medical science's basic weapon against allergy. The physician first injects an extremely small amount of the offending substance into the patient's system. Gradually, he increases the amount that is injected. In time, the patient's body becomes accustomed to accept large amounts of the material without experiencing any allergic effects.

In the case of a seasonal allergy, injections may be given once or twice a week for several months before the start of each pollen season; or else, after the first year, the patient may be injected once every two or

Insect stings, such as those from the bee (lower left) and the wasp, may cause severe allergic reactions in some individuals. Certain plants, such as poison ivy, poison sumac, and poison oak, very commonly cause allergic reactions through contact.





Both photos, R. L. Peterson

The intradermal test for allergic sensitivity. In this procedure, a small amount of the suspected allergen is injected directly into the skin of the patient. In the upper photo, the allergist is injecting the arm with an allergen dissolved in a solvent. He makes a series of injections, alternating allergens and solvents with solvents only. In the lower photo, we see the results of the test. The patient has reacted to each of the allergen and solvent injections, but not to the injections of solvent alone. When such tests are given, antidotes should be readily available—in case a patient should develop a severe allergic reaction.

three weeks on a year-round schedule. Either method will usually prevent or reduce attacks of seasonal hay fever. At least two full years without any signs of allergy are necessary before hyposensitization can be stopped. Even then it must be remembered that the symptoms can reappear at any time.

One widely held belief about allergy is that children outgrow it. This is not true. If one ignores early signs of allergy in the hope that they will disappear by themselves, the results will be unfortunate and often tragic. Even if the first signs of allergy should clear up without treatment, as sometimes happens in rare cases, the allergic tendency would still be present and might cause more serious trouble in the future. The best time to treat allergy is when it first appears. Even a young infant can be hyposensitized by an experienced allergist.

Drugs. In recent years, great progress has been made in relieving the major symptoms of the common allergies. The *antihistamine drugs*, although not the cure-alls they were once thought to be, can be very useful in providing temporary relief in minor allergies. The *steroid hormones*—*cortisone* and *hydrocortisone* and their synthetic substitutes—can also be of extreme value in some instances. Both the antihistamines and the steroids, however, are generally used only for temporary relief until hyposensitization can take effect.

The conventional approach to treating allergy has emphasized identification of allergens, treatment with drugs, or hyposensitization. But new treatments may arise with increased understanding of the mechanism of allergy reaction. Work with conjugated allergens (complexes of antigen with chemicals) suggests that it may be possible to control Ig E production and the level of Ig E in the blood. As a possible key to improved allergy therapy, scientists are studying an enzyme called adenyl cyclase, which influences the release of mediators.

Allergists expect that, eventually, specific drugs will provide immediate relief and even permanent protection. This would represent a major and perhaps conclusive victory in the continuing campaign against the ravages of allergic reactions.

There is ongoing search for influenza vaccine that will be effective against several types of influenza. Here Belgian researchers are involved in testing a live-virus influenza vaccine.

SmithKline Corporation

INFLUENZA

by Lawrence K. Altman, M.D.

It comes on suddenly, with a headache. A feeling of malaise. Muscle aches. Chills. Sneezing. In just a few hours the temperature rises to 38.3° Celsius or higher. The eyes tear, even ache. A hacking cough begins, usually dry and nonproductive of sputum. Many, but not all victims sneeze, have runny noses, and develop sore throats. Some experience an upset stomach and diarrhea.

These acute symptoms generally last three days, but some people recover in one day. In others, the symptoms may persist six days. Even after a person recuperates and can get out of bed, the cough and a feeling of weakness can continue for two or more weeks.

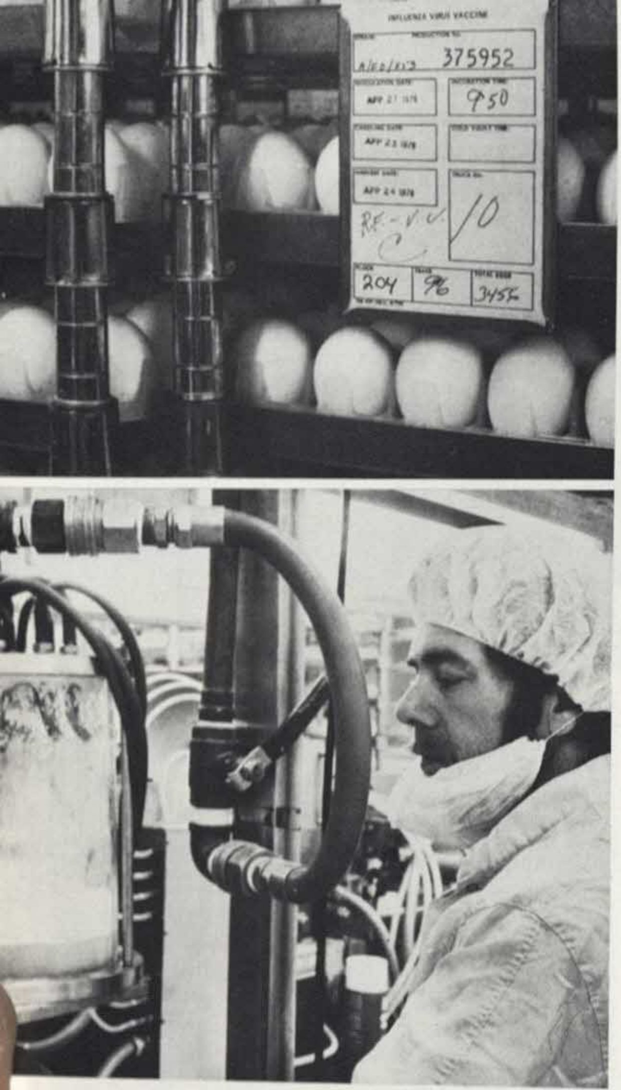
This is the typical attack of influenza in humans. It infects animals, too, and just as seriously. Human influenza is a viral infection whose seriousness the public often underestimates. Yet it is one of the most serious and mystifying diseases. Public health officials consider it the most important epidemic disease that is still uncontrollable in the United States. It is also still uncontrollable in many other countries with generally high standards of public health.

A VERY COMMON AILMENT

Influenza is also one of man's most common ailments—so common that the nickname "flu" has come to describe a severe common cold as well as influenza. Without the aid of laboratory tests it may be difficult for a doctor to distinguish the common cold from some cases of influenza. In general, colds are milder. They are caused by hundreds of viruses with different names. However, influenza is caused by the influenza virus, of which there are many subtypes.

Influenza is primarily a disease of the respiratory tract. It infects the cells of the nose, the windpipe, and the air sacs in the lungs. The virus that causes influenza is spread in droplets when the infected person sneezes or coughs. Usually two days are needed for the virus to incubate in a patient's body before it suddenly produces the classic symptoms of an influenza attack. But sometimes the incubation period is as short as a few hours, and in other cases as long as one week.

Once exposed, the influenza victim can begin spreading the virus 24 hours later and can keep on spreading it for about a week.



UPI

When there was widespread fear of a swine flue epidemic, researchers rushed to develop a vaccine against it. Top: eggs inoculated with swine flu seed being incubated. Lower: fluid taken from the eggs is harvested and collected to be used in preparing swine flu vaccine for humans.

This is a relatively short span as infections go, but one influenza victim can pass the virus on to scores of people in the few days, and they in turn to hundreds more, setting in motion the chain of events that produces an explosive outbreak, if not an epidemic.

POSSIBLE SERIOUS EFFECTS

Influenza can kill directly by its action on the respiratory system. But the more usual cause of death is a secondary pneumonia due to invading staphylococcal bacteria or other bacteria. The influenza virus' attack on the lungs and immune system seems to break down the patient's resistance, making the individual more susceptible to the secondary infection.

Although most victims survive, the outbreak of influenza seriously disrupts the economy. Such costs are among the reasons public health officials follow influenza activity so closely.

NEW STRAINS DEVELOP

In 1976, influenza attracted enormous public attention throughout the world because of a new strain of influenza virus discovered in a small outbreak among military personnel at Ft. Dix, New Jersey, in the United States. It resembled the swine strain believed to have caused the 1918–1919 epidemic of influenza, one of the worst epidemics in history.

The new virus was officially called influenza A/New Jersey, but virtually everyone knew it by the nickname *swine flu*. The discovery of the virus and concern that it could lead to an explosive epidemic led the U.S. government to spur drug companies to rapidly make enough vaccine against the new strain to inoculate every American. The plan came under attack as soon as the program started, and government officials were forced to stop the injections after the discovery of an apparent link between the vaccine and a temporary paralytic condition called Guillain-Barre syndrome.

NOT A NEW DISEASE

Although the A/New Jersey (swine) strain was new, it was still a variety of the virus that has caused epidemics for centuries. No one is sure when the first outbreak occurred, but some medical historians believe that epidemics of influenza, although not called by that name, were described as early as Hippocrates about 400 B.C.

What now appears to have been influenza was called by various names until the beginning sixteenth century, when the Italians introduced the name influenza, at-

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The success of any vaccination program depends not only on the effectiveness of the vaccine but also on the care and speed with which it can be distributed to a large segment of the population. Here, workers carefully package vials of vaccine for shipment.

tributing the occurrence of an outbreak at that time to the influence, or *influenza*, of the stars and heavenly bodies. About two centuries later the English adopted the name influenza, and in the eighteenth century the French added the term *grippe* to the vocabulary that describes influenza.

However influenza has been described, epidemics have occurred periodically at irregular intervals. The least predictable feature about influenza is just when a new epidemic will come. The most predictable point is that another epidemic will occur. Even more mystifying is another predictable feature: when epidemics occur, they invariably occur in the winter season. The influenza virus is destroyed when exposed to sunlight, and one theory advanced for the seasonal pattern is that people tend to stay closer together indoors in the winter. This increases the likelihood of the disease spreading. In the summer, on the other hand, the viral droplets become diluted in the sunlight, and people are more dispersed. However, no one is able to explain fully the oddity that influenza in horses does not follow the same seasonal trends as in humans. Most horse outbreaks have been in the spring and summer.

WHAT ABOUT THE VIRUS?

Influenza has been as well studied as perhaps any other virus. Yet scientists still know very little about just how it causes an epidemic and whether there are a limited or an endless number of influenza viruses in nature. Nor do scientists know precisely what the virus does in the infected person or animal, how to make a vaccine that will control, if not eradicate, the infection, and how to develop effective drugs or other therapies.

Of all influenza epidemics, the 1918–1919 epidemic may have been the worst. Millions of people died of influenza throughout the world. About one half of the deaths were in the 20 to 40 age group.

The 1918–1919 epidemic occurred before doctors knew that a virus caused influenza, and little is known about the viruses that caused earlier outbreaks and epidemics. In fact, the 1918–1919 epidemic came only a few decades after the idea that infections were contagious had been generally accepted.

Even now, scientists have not identified the virus responsible for the 1918–1919 pandemic. But from blood samples taken from people who were alive at that time, doctors now believe that the pandemic was caused by a swinelike strain of influenza virus.

The identification of the influenza virus, like the discovery of some other disease-causing organisms, came about through the contributions of veterinarians. A veterinarian who had observed a disease in pigs thought it was the same as the 1918 pandemic, but there was no laboratory proof. In 1928, veterinarians transmitted influenza from pig to pig by injecting mucus taken from the respiratory tracts of sick pigs into the noses of healthy pigs. That proved it could be passed from one person to another, but it did not identify the causative organism. When the experiments were repeated, using material that had passed through a fine filter, scientists knew the causative agent must be a virus. Bacteria and most other known disease-producing organisms cannot pass through a fine filter. Viruses – very small organisms – can. In 1931, the virus was isolated from swine.

In 1933, cultures taken from the throat of a human influenza victim were filtered and the material injected into ferrets, which then developed influenza. These experiments demonstrated that a virus caused influenza in humans.

Over the next few years, scientists learned that there were three main types of influenza, called A, B, and C. Since then, epidemiologists have learned that Type A is the most important because it seems to be the one that causes serious worldwide pandemics. Type B also causes epidemics, but less frequently. Type C is uncommon.

When seen through the electron microscope, the three types of influenza virus are indistinguishable from one another. They appear as spherical viruses about 1/10,000 millimeter in diameter. But they do differ in the chemical substance that they release in the body. Infection with one type does not confer immunity to another type. Each of the three main types has subtypes, and within subtypes there are variants.

Although the composition of the virus is known, how it infects humans remains a puzzle. The surface of the virus is covered with two kinds of spikes. One is called hemaglutin (H) because in laboratory tests it causes the clumping or agglutinating of red blood cells. The other is called neuraminidase (N), which is an enzyme. Because H and N are the antigens against which the body produces antibodies, they are considered the most important of the influenza virus' four antigens. The other two antigens are in the core that consists of RNA (ribonucleic acid) genetic material. The core antigens do not lead to the production of an antibody.

A CHANGEABLE VIRUS

Influenza viruses have a unique property. The character of the H and N antigens can change spontaneously in profound ways through a phenomenon called *antigenic shift*. When these antigens change in minor ways it is called *antigenic drift*. A shift can be likened to a change in color and a drift to a change in shade of the same color. It is the creation of new shifts that leads to major pandemics. Drifts more generally lead to localized outbreaks or small epidemics.

Virologists believe that the life span of a human influenza subtype is from one pandemic to the next. This reflects another phenomenon of influenza. Arrival of a new subtype ousts the old one. Whereas there are concurrent multiple subtypes and variants of other viruses, only the influenza virus seems to behave by annihilating older forms.

Influenza Type A pandemics and antigenic shifts are not regular events. Most recently, they occurred in 1918, 1957, and in 1969, periods separated by 39 and 12 years, respectively.

TRYING TO PREDICT OUTBREAKS

Scientists have yet to find a way to predict accurately just when a new influenza epidemic will occur or what changes in antigenic character will arise. Yet there is a tremendous need to develop the capacity for such predictions. The reason is that the major threat of influenza to humans is the possibility of the emergence of a highly virulent strain that could produce pandemics, decimate populations throughout the world, and affect young and healthy people as well as the chronically ill and elderly.

Experts contend that they know of no reason why a pandemic as devastating as or even more horrendous than the 1918 – 1919 pandemic might not be on the horizon. For a better understanding of how and at what rate influenza spreads – its epidemiology – the strains of influenza virus must be isolated and identified as early as possible.

In 1947, to establish a quick influenza identification system, the World Health Organization in Geneva, Switzerland, set up an international network of collaborating laboratories to monitor the disease. The aim is to isolate viruses when and where outbreaks of influenza occur and to determine their similarities to, or differences from, previously identified strains. The number of collaborators in this program has gradually increased to a total of 97 laboratories in 69 countries. Even with the network, there are large areas of the world that are poorly monitored, however.

VACCINES—AN ANSWER?

A chief benefit of the surveillance system is to allow a longer lead time in preparing new vaccines. The newest strain of influenza virus must be included if a vaccine is to provide maximum chance of protection against infection. The first vaccine was developed in 1943. Since then vaccine developers have increased the potency of the influenza vaccine while at the same time decreasing its toxicity. The currently used vaccines are up to 80 per cent effective, but immunity generally lasts only one year. Because these vaccines are still far from perfect, a major goal of influenza experts is to improve existing vaccines.

The chronically ill and the elderly are the most seriously affected by an attack of influenza, and are frequently the first vaccinated when an outbreak threatens.

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Further, some scientists doubt that vaccines alone will ever provide optimal control of influenza. Accordingly, many scientist are trying to develop effective drug therapies that could be given either in conjunction with vaccine or independently. Amantadine is one drug that has been tested, but its usefulness is considered limited because it seems to work against influenza A virus only. However, that alone has been enough to encourage pharmacologists to seek other drugs that might be useful against influenza.

Although the influenza virus was first discovered in the pig, scientists paid relatively little attention to animal influenza until recent years. In the late 1950s, the World Health Organization began a survey to detect evidence of influenza in animals, and it found many influenza A subtypes in a variety of domestic and wild species such as swine, horses, dogs, and birds. The illness in animals sometimes is remarkably similar to that in humans, with herds or flocks sometimes prostrated for several days and the animals breathing laboriously. But it is not clear what role animal influenza viruses have in producing the illness in humans.

STILL LEARNING ABOUT IT

Among the reasons for the renewed interest in animal influenza was the surprising discovery in 1974 that influenza viruses can be isolated more frequently from the cloaca (an excretory receptacle) than from the respiratory tract of migrating birds. The finding raises the possibility that in animals influenza virus might be shed in droppings and not through the respiratory system. It is these and other observations on the ecology of wildlife that may help unravel just how influenza spreads among animals and humans.

ARTHRITIS

by Suzanne Loebl

Arthritis is mankind's oldest known chronic disease. The disease plagued the Java, Lansing, and Neanderthal men who lived more than 400,000 years ago. Arthritis is also one of mankind's commonest chronic diseases. Today in the United States, arthritis, or rather the *arthritides,* a group of arthritislike diseases, affect over 20,000,000 people seriously enough to require medical care. Another 35,000,000 people have the disease to a minor degree and manage on their own.

The word arthritis means joint *(arthro)* inflammation *(itis).* Painful, swollen joints are one of the major characteristics of a group of about 80 different arthritis-related conditions that include *osteoarthritis, rheumatoid arthritis,* and *gout* as well as some less well-known disorders such as *systemic lupus erythematosus, scleroderma,* and *ankylosing spondylitis.*

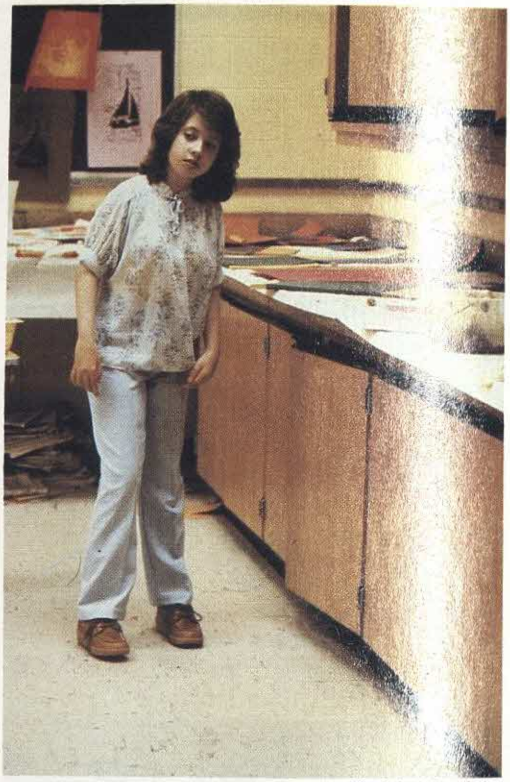
Arthritis-related diseases are not restricted to humans. Evidence of joint deterioration has been detected in the skeleton of the 100,000,000-year-old swimming reptile, platecarpus, and the horse and the dog suffer from the diseases.

OSTEOARTHRITIS

Osteoarthritis is the most common form of arthritis. It is sometimes called the wear-and-tear disease. Indeed the X rays of 95 per cent of persons over the age of 65 show some evidence of joint erosion. The changes that take place in an osteoarthritic joint are very similar to those seen in other forms of arthritis.

Osteoarthritis can be primary, starting without any apparent provocation, or secondary, occurring as a result of one-time or repeated trauma, or injury. Football players commonly have arthritic knees, ballet dancers arthritic toes, and keypunch operators have trouble with the index finger joint.

Osteoarthritis often affects only a single joint in the body. The cartilage, or soft elastic tissue surrounding the joint, is often the first part affected. The first noticeable change is a softening, pitting, and fraying of the smooth cartilage surface, followed by loss of elasticity. Pain and impaired mobility are common early symptoms.



The Arthritis Foundation

Rheumatoid arthritis is a common form of the disease, and often occurs at an early age.

Treatment of osteoarthritis is aimed at suppressing the inflammation. If only one joint is affected, this is sometimes handled by local injection of an anti-inflammatory drug. Much progress has been made in the surgical treatment of osteoarthritis, and total joint replacement has been highly successful.

RHEUMATOID ARTHRITIS

Rheumatoid arthritis is the second most common form of arthritis. In the United States alone, it affects about 5,000,000 persons—three times as many females as males. It may occur at any age, frequently starting in early adulthood.

Unlike localized osteoarthritis, rheumatoid arthritis is systemic, meaning that it affects the entire body, sometimes causing fatigue and weight loss. An abnormal protein called the *rheumatoid factor* is present in about 75 per cent of patients with rheumatoid arthritis.

Rheumatoid arthritis usually affects symmetric joints. Thus, if the joint in the third finger of the left hand is affected, so, usually, is the corresponding joint in the right hand. The disease, like all forms of arthritis, is highly variable, its symptoms and course differing greatly among individuals. No two patients are exactly alike. This makes the diagnosis of the disease difficult.

Rheumatoid arthritis is a chronic disease. Fortunately, however, one of its startling features is that it often comes and goes. Even patients with severe disease have periods during which they feel free of symptoms.

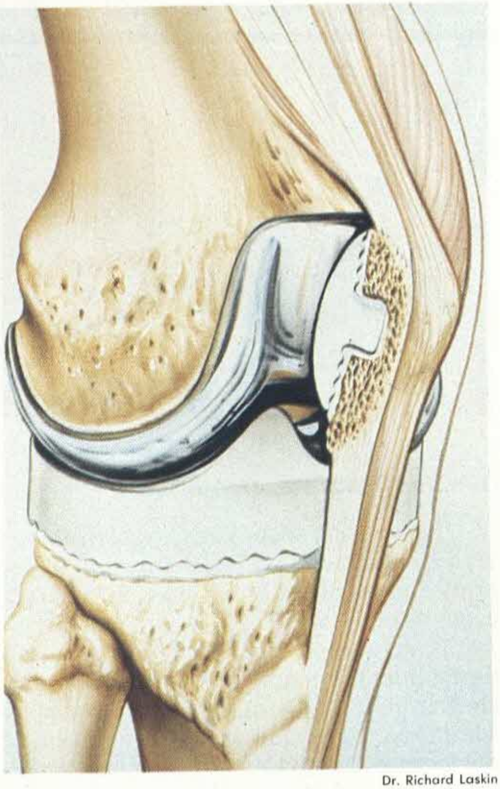
The treatment of rheumatoid arthritis is complex, involving the use of drugs such as pain killers and anti-inflammatory agents as well as rest and exercise.

Rheumatoid arthritis sometimes affects children. In the United States about 250,000 children are afflicted with juvenile rheumatoid arthritis. The great majority of these children outgrow the disease, but often only after many years of suffering.

GOUT

Gout is a metabolic disease associated with acute attacks of arthritis. It is a form of arthritis that can be treated very successfully. Patients suffering from gout have a defect in the way they handle uric acid, a key organic degradation product of proteins and purines.

For a variety of reasons—mainly either an overproduction of uric acid or too little urinary excretion of uric acid—gout patients have too much acid in their blood. This acid can crystallize out, much as sugar crystals collect at the bottom of a jar of honey. During an acute attack of gout, uric acid crystals become lodged in a joint—the big toe joint being a favorite target. There the acid crystals initiate the inflammatory process.



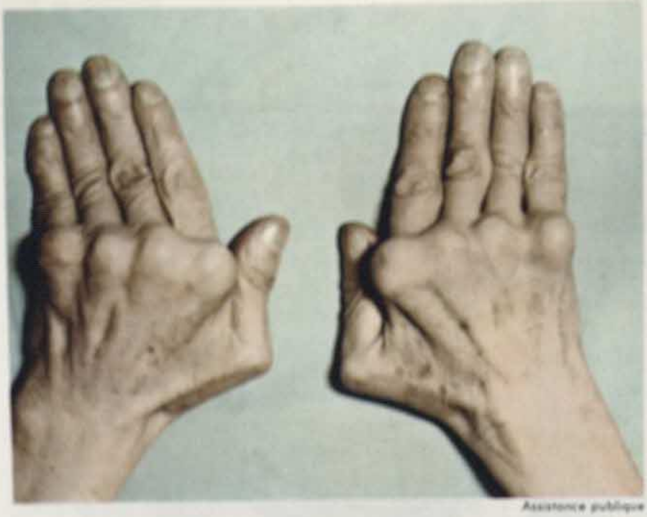
Dr. Richard Laskin

Joints, like the knee, damaged by arthritis, can now be replaced with artificial ones.

Some drugs, such as allopurinol, colchicine, and probenecid, can correct the defect in uric acid metabolism—either by preventing excess formation of uric acid or by speeding up its elimination in the urine. Today few patients with gout need to suffer any of the overt symptoms of the disease, although the underlying condition that causes the gout will not be cured by these chemical treatments.

INFECTIOUS ARTHRITIS

Common infectious agents, such as those that cause tuberculosis, gonorrhea, or staphylococcus infections, can become lodged in joints, where they cause intense inflammation. The recent upsurge in venereal disease has led to an increase in infectious arthritis. Infectious arthritis is a medical emergency, because it can lead to rapid cartilage destruction. It is, however, easily treated with suitable antibiotic agents.



Osteoarthritis, the "wear-and-tear disease," may cause deformation of the joints in elderly persons.

Assistance publique

OTHER FORMS OF ARTHRITIS

Ankylosing spondylitis, systemic lupus erythematosus, and scleroderma are all serious forms of arthritis that fortunately occur rarely.

Ankylosing spondylitis occurs ten times more frequently in men than in women. It usually begins in adolescence or early adulthood. Untreated, it results in fusion of the spine and consequently impaired movement. In 1973 it was discovered that the great majority of patients suffering from ankylosing spondylitis have a characteristic genetic marker, HA W-27. This marker could be used to identify persons at risk of developing ankylosing spondylitis.

The finding of HA W-27 is also an important discovery from a research point of view, since it and other yet-to-be-discovered genetic markers may give a clue as to what type of person is at risk of developing arthritis.

Systemic lupus erythematosus is a cousin of rheumatoid arthritis and, like reumatoid arthritis, affects more women than men. It is associated with a disorder of the immune system and affects many organs.

Scleroderma means a "hardening of the skin." It involves an overproduction of the protein collagen, the main constituent of cartilage and other types of connective tissue. Such overproduction eventually results in the choking of vital organs. Skin that looks and feels too tight is a characteristic of this disease.

THE INFLAMED JOINT

Joint inflammation is the common ground of the arthritis-type diseases. A *joint* is the junction between two or more bones. Bone ends are usually capped by cartilage, a soft, elastic tissue, which is the precursor of fully mineralized bone. The joint itself is enclosed in a *joint capsule* that is lined by a thin lining—the *synovium*—and filled with a lubricant—the *joint fluid*. The joint is operated—flexed, stretched, rotated, opened, and closed—by a system of muscles and tendons.

The initial step that triggers inflammation is not known for most forms of the arthritide diseases, but much of what happens once the inflammation is underway has been elucidated.

Any type of inflammation—including an inflamed arthritic joint—is characterized by heat, pain, swelling, and redness. The joint feels hot when touched, is intensely painful, swells, and may appear red.

Inflammation is a normal physiological mechanism, an attempt of the body to rid itself of something it considers foreign. The enemy can be many things—a splinter, a foreign protein, a transplanted organ, a particle of some sort, or a virus.

ANTIBODY PRODUCTION

The body reacts to such provocation with both *humoral* and *cellular* responses. The humoral response refers to the special proteins—antibodies—that the body manuactures when it encounters a foreign substance, or *antigen*. An *antibody* is generated against a specific antigen and combines with it, thus neutralizing the antigen. In the normal course of events, the antibody-antigen complex is somehow disposed of. Antibodies are made by specialized white blood cells called *plasma cells*.

CELLULAR RESPONSE

The cellular response of the body also involves the white blood cells – one type of white cell in particular, the *phagocyte*, or eating cell. Phagocytes are supposed to physically remove an offender, including the antigen-antibody complexes, from the scene of the battle. The phagocytes have been compared to foot soldiers. Their function is to swallow and digest the enemy. To this end they are equipped with special corrosive enzymes – the *lysosomal enzymes* – inside special little sacs called *lysosomes*. Unfortunately, sometimes the phagocytes swallow more than they can chew. Instead of neatly digesting their prey, they burst open, and the contents of the cells, including the corrosive lysosomal enzymes, escape into the surrounding tissues.

DESTRUCTION OF CARTILAGE

In arthritis, the lysosomal enzymes escape into the joint cavity and attack the synovial membrane. This initiates the inflammatory process. The synovial membrane thickens. More white cells come to the battle scene. More lysosomal enzymes pour into the joint cavity. Sometimes the confrontation results in a *pannus*, or pileup of synovial lining cells and defender cells. When this happens, the inflammation is then feeding on itself.

Eventually the cartilage becomes inflamed and is gradually destroyed. It too may attempt a repair, which sometimes takes the form of overstimulation and overgrowth. In some cases arthritic joints become fused.

ANTI-INFLAMMATORY AGENTS

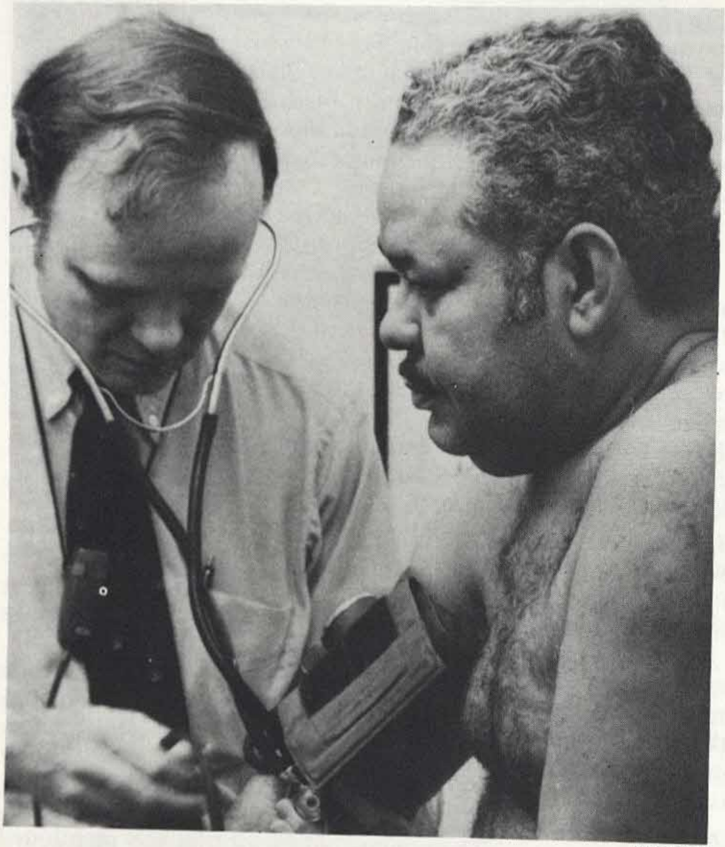
Inflammatory processes are seldom allowed to run their course today. There is a whole army of anti-inflammatory agents that suppress inflammation. Some of the more familiar drugs used for this purpose are aspirin, gold salts, and cortisone. Some of the newer *cytoxic agents*, which suppress the white blood cells, are being used to treat rheumatoid arthritis on an experimental basis.

Unfortunately none of these drugs can do more than suppress the inflammatory process of arthritis. They do not cure the disease, because the factor that triggers the whole process of the arthritic attack is still unknown.

IMMUNE FACTORS

There is increasing evidence that some, but not all, forms of arthritis are associated with a disorder of the immune system of the body. The details of the immune disorder are not yet known, but patients suffering from rheumatoid arthritis, for example, are known to have abnormal antibodies. In addition, a portion of the antibody-antigen complexes in these patients then reacts with some sensitive receptor sites located along the blood vessels, in the kidneys, and in the synovial membranes. In turn, the body also may make antibodies against these antigen-antibody complexes. The rheumatoid factor that was mentioned earlier in the article is one example of such an antibody.

There is still more evidence that the immune system may be involved. The white blood cells of patients suffering from some forms of arthritis have lost the ability to tell self from nonself. In other words, they do not clearly recognize an enemy. These patients then make antibodies against some of their own tissues. This is perhaps why their antibody-antigen complexes are not cleared away as they would normally be. In some forms of an immune system disorder – systemic lupus erythematosus, for example – patients make antibodies against their own nucleic acids. Such anti-nuclear antibodies are important for the diagnosis of these diseases. These abnormal immunological complexes produced by the body may very well play an important role in triggering self-perpetuating joint inflammation.



Wide World

Louis Russell, the world's thirty-fourth recipient of a heart transplant, is examined by his cardiologist, Dr. Robert Chevalier. Russell's body tried to reject the transplanted heart on at least four occasions. Each time, the rejection process was overcome by increasing the dosage of immunosuppressive drugs, and Russell lived for eight years after his transplant operation.

ORGAN TRANSPLANTS

by James D. Hardy and Fikri Alican

"I'm going to live," said Louis B. Russell, Jr., as he entered the surgery room at the Medical College of Virginia. During the next four hours a team of doctors headed by surgeon Richard R. Lower performed the world's thirty-fourth heart transplant. They replaced Russell's diseased heart with the healthy heart of a 17-year-old gunshot victim. That was on August 24, 1968.

After that time Russell's life changed: the 45-year old father of three became more active than ever. He taught industrial arts five days a week at a junior high school in Indianapolis, Indiana. In addition, he made as many as ten speeches a week to local and state organizations. He drove a car, rode a bike, and repaired the roof on his home.

In April 1970 the energetic Russell became the world's longest-surviving heart recipient. "I knew I was going to get this far," he said. His doctor, Robert B. Chevalier, whom he was visiting three times a week, commented: "If they were all like this, we'd be doing heart transplants every day."

In 1976 Russell died. His transplant was nonetheless considered a success. He had lived eight years more than he probably would have without his "new heart."

FROM ONE TO ANOTHER

The history of transplant operations did not begin in the twentieth century. Rather, it dates back to the Hindus who lived hundreds of years before the first century A.D. There are accounts of transplantations from that time until the present. Some are believed to be more fiction than fact, but others are considered true.

The early operations that were successful were *autografts,* operations in which the graft is from one part of a person's body to another part of his body. This process is valuable in grafting skin, blood vessels, and nerves. But if a person has a diseased heart or liver that must be replaced, the replacement must come from another organism. If the donor organism is of the same species as the recipient, we call the transplant a *homograft*. Transplanting a heart from one human being to another is a homograft. Transplanting a kidney from a dead dog to a living dog is also a homograft.

Surgeons have also experimented with grafts between different species, as from a dog to a sheep, or a chimpanzee to a man. These are called *heterografts*.

REJECTION

Transplantation of organs from one human being to another has been successfully done only since the 1950s. In October 1954, Richard Herrick, a 24-year-old U.S. Coast Guardsman, lay dying of kidney disease at Peter Bent Brigham Hospital in Boston. Richard's identical twin, Ronald, was willing to donate one of his healthy kidneys to his brother. In a two-hour operation, doctors removed the kidney from Ronald and grafted it into Richard's abdomen.

Previous kidney transplants had been technically successful, but the patients had died within days or weeks of receiving their new organs. Richard was the first patient to survive for a long period of time and to lead a normal, active life. He died in 1963 of heart disease and pneumonia.

Since that time doctors have been technically successful in transplanting almost all of the major organs except the brain. But many of these technical successes have not been followed by long life. Too often the patient dies soon after the operation. The cause of the death: rejection of the donor organ by the patient's body.

Why does rejection occur? Every individual contains a variety of large, complex molecules called *antigens*. These are inherited characteristics. Different people have different combinations of antigens. You have probably heard of some of the antigens that may be present in a human being. For example, the A, B, and Rh antigens found in blood. Viruses, bacteria, and other organisms also have antigens.

If such antigens get into a human being, they may cause diseases. To protect against such diseases, lymph cells in the body produce *antibodies*. These protein substances destroy antigens that do not naturally occur in the body. This would include bacterial antigens, mouse antigens, monkey antigens, even human antigens that have not been inherited by that person. Antibodies, as you can see, are a very valuable defense against germs that cause diphtheria, pneumonia, and other diseases. But they present a major problem in a transplant operation. If the donor organ contains certain antigens not found in the recipient, the recipient's body makes antibodies that fight these strange antigens. In the process the donor organ is destroyed, or rejected.

TREATING REJECTION

Doctors now use three methods to prevent or diminish the intensity of the rejection phenomenon: radiation, immunosuppressive drugs, and tissue typing.

Radiation. Doctors have found that X-ray radiation, applied at the site of the graft and at sites where antibodies are produced, will decrease the chances of rejection. However, radiation is, at best, only a partial solution. The doses needed to completely prevent rejection are so great that they would also cause severe damage or death to the cells in the patient's body.

Immunosuppressive drugs. These are drugs that suppress the production of antibodies. At the present time three such drugs are in common use: azathioprine, cortisonelike substances, and antilymphocytic globulin (AIG), a substance produced in horses and other animals that have been sensitized to react against human lymph cells. Doctors use different amounts and combinations of these drugs. They are given to the patient as long as the graft survives. But immunosuppressive drugs have one very important drawback: not only do they suppress the production of antibodies that fight transplanted organs, but they also deprive the person of antibodies that fight infectious diseases, making him overly susceptible to invading germs. Consequently, infectious diseases such as pneumonia have caused the death of many transplant recipients whose new organs were functioning satisfactorily. In an effort to avoid this, doctors try to administer the drugs in amounts sufficient to prevent rejection of the transplanted organ without dangerously lowering the body's ability to fight disease. They also use antibiotics to help control any infections.

Tissue typing. There is one situation in which rejection isn't a problem. If the donor and recipient are identical twins such as Ronald and Richard Herrick, the transplanted organ is not attacked by antibodies. Why? Because the twins are genetically alike. They have inherited exactly the same antigens. Thus no antigen in the donor organ is "strange" to the recipient.

Scientists have learned that the antigens which sensitize a recipient to the grafted organ are found in white blood cells called lymphocytes. Any grafted organ will contain lymphocytes, not only in its blood vessels but also in the lymph vessels and in the spaces between the organ's cells. They also learned that by determining which antigens are found in a person's lymphocytes and then closely matching the donor and

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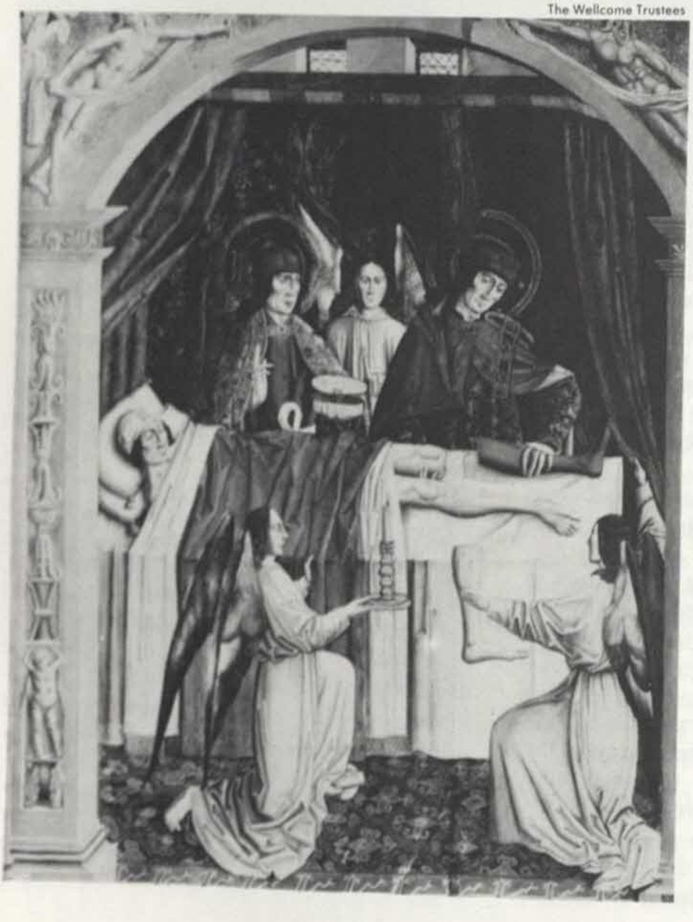


Many legends of transplant operations have persisted for hundreds of years. One of the most dramatic tells of a homograft performed by Saints Cosmas and Damian. According to the legend, the saints removed a gangrenous leg from a patient and replaced it with the healthy leg of a Negro who had just died. When the patient awoke, he had two sound legs: one white and one black. The legend is the subject of this painting by Alonso de Sedano.

the recipient with respect to these antigens, they would have a better chance of a successful transplant. The process of determining which antigens are present in the lymphocytes is called tissue typing. It is very similar to blood typing, which determines which antigens are present in red blood cells.

In recent years more than 25 different white-blood-cell, or tissue, antigens have been recognized. A given person may have any number and combination of these. For this reason, the probability that any two persons will have exactly the same antigens is very, very small. But tissue typing allows doctors to select the available donor organ best matched for a waiting recipient.

Studies of graft-survival rates have shown that, in general, the greater the compatibility of the tissue types, the greater the survival rates. This is especially true in cases where patients survive for more than three months. For example, a study at the University of Colorado Medical Center in Denver found that 38 per cent of the early patients receiving kidney transplants from unrelated donors survived at least a year. But after tissue typing was insituted and donor and recipient were closely matched, the one-year-survival rate jumped to 79 per cent.

Good tissue compatibility also decreases the chances of rejection episodes—crisis periods during which the patient must be given exceptionally heavy doses of immunosuppressive drugs to overcome antibody production.

There are probably some important tissue antigens that have not yet been recognized. Once all such antigens have been defined and doctors can graft organs with a minimum number of "strange" antigens, survival rates will undoubtedly increase greatly.

FINDING DONORS

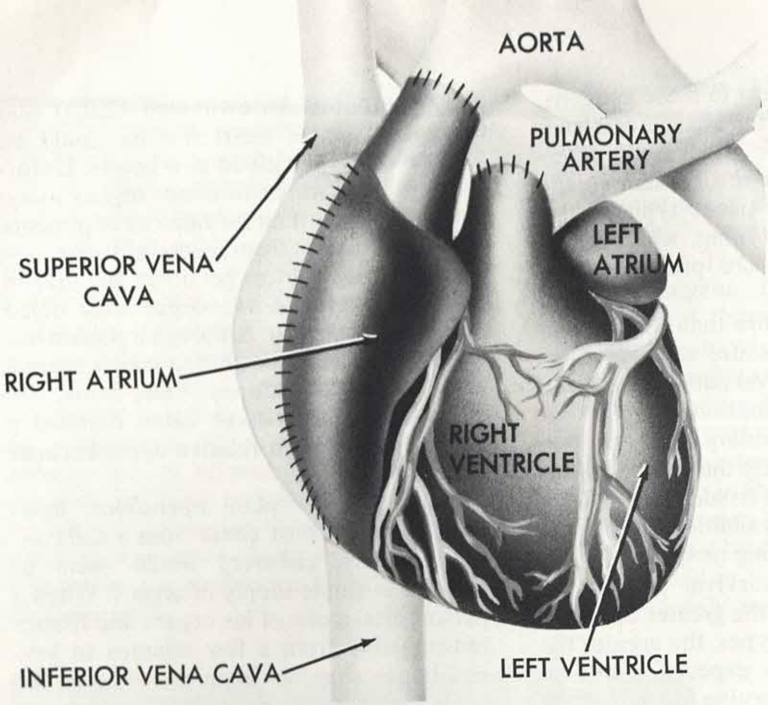
Many thousands of people, afflicted with fatal diseases, could benefit from organ transplants. For example, in the United States approximately 40,000 persons die each year from kidney disease. An estimated 6,000 to 8,000 could be saved by a transplant operation. An estimated 32,000 who die each year of heart disease could be saved if they were given new hearts. Unfortunately the number of donor organs available is far fewer than the number of patients who could benefit from receiving them.

Where do doctors get donor organs? In a kidney operation the organ may come from a living person. Although a person has two kidneys, it is possible to lead a normal life with only one kidney. Thus twins, siblings, and parents have often donated a healthy kidney to a relative dying because of kidney disease.

In most transplant operations, however, the graft must come from a cadaver. Theoretically, cadavers would seem to provide an ample supply of organs. When a person dies, many of his organs and tissues remain alive from a few minutes to several hours after the brain is dead and the heart has stopped. Brain death, which can be diagnosed in a clear-cut manner, means that the person will not come back to life no matter what is done. From such bodies even the stopped heart is transplantable if this can be done without delay.

However, only a small fraction of cadaver organs can be used in actual practice. Organs of people dying of cancer or infectious diseases cannot be used. Nor can doctors use organs of people who die slowly, with a long terminal period characterized by low blood pressure. In such cases all organs deteriorate. Organs of elderly people also present drawbacks.

The most suitable cadaver is a young person who has died from a severe head injury. However, the transplant surgeons must have legal permission for the donation before they can remove an organ. During the time needed to contact the next of kin and receive their approval, the organs often lose their viability and cannot be used. In the United States this situation may be rectified by the Uniform Anatomical Gift Act. This act provides that an individual may donate all or any part of his body for medical use, the gift to be effective upon his death. To make such a donation the person need simply sign a Uniform Donor Card before two witnesses. This card, designed



This diagram shows the surgical technique developed by Dr. Shumway. Part of the recipient's right and left atria remain intact. The donor heart (darkened structure) is then attached to the atrial sections, the aorta, and the pulmonary arteries.

to be carried on the person, provides a method by which the wishes of the individual have the greatest likelihood of being followed immediately after his death.

Speed, as we indicated, is essential if the organs are to be usable. To preserve a donor organ it should be removed immediately after death. Special precautions also have to be taken to keep the organ alive until it is connected to the recipient's circulation. Surgeons have developed various machines to maintain organs while they locate and prepare suitable recipients.

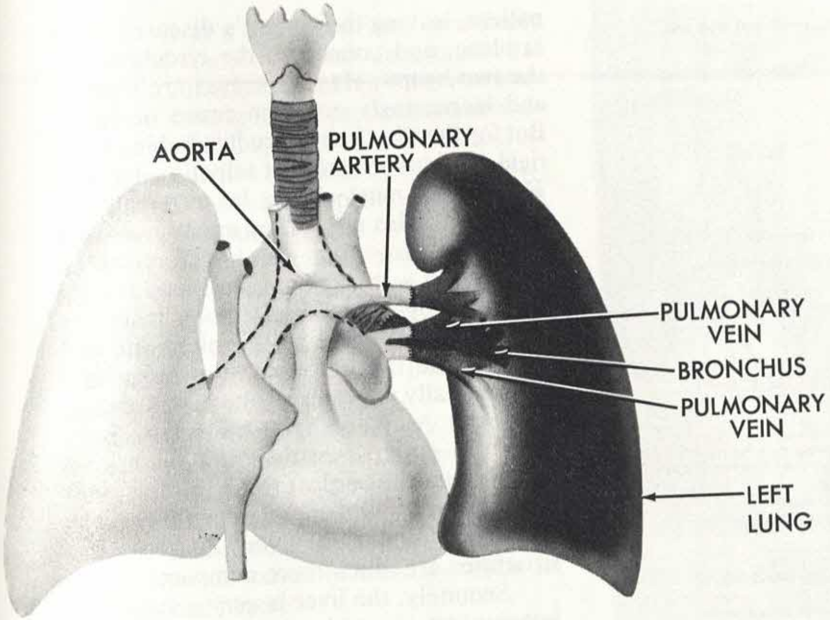
The lower temperature of the organ during this interim period, the longer it will stay alive. Long-term storage of organs below freezing temperatures would be very desirable and would make it possible to establish extensive organ banks. In this way, cadaver organs could be stored for weeks, months or even years, and used when—and where—required. However, organ banks in this sense do not exist—except in the case of the cornea of the eye, which is often used as a homograft. At present, only techniques for short-term storage (from a few hours to a few days) have been developed, and even these are not yet available on a wide scale.

Sometimes an organ goes to waste because a suitable recipient cannot be found. This problem is being solved through the formation of multihospital organ registries. One of the first such registries was established in Los Angeles. Patients awaiting, for example, a kidney transplant are tissue-typed at the time their doctors decide that a transplant operation is desirable. When a donor kidney becomes available it is typed and compared with the tissue types of all potential recipients listed in the registry. The recipient with the best match will receive the organ.

A similar program in Europe, Eurotransplant, involves hospitals in five nations. A donor organ that becomes available in Belgium may be flown to a waiting recipient in Switzerland. The kidneys of a man killed in auto accident in West Germany may be transplanted into Dutch and British patients. Another such program, Scandiatransplant, operates in the Scandinavian countries. As methods of preservation improve, such interhospital and international programs will probably increase in size and number.

SURVIVAL RATES VARY

In the following paragraphs, we will take a brief look at the major organs that have been transplanted in man. In general,



This diagram illustrates the surgical connections involved in transplanting a lung. As with other transplants, no nerve connections are made.

the techiques used were developed earlier in transplant operations on experimental animals such as dogs and chimpanzees. For example, hundreds, perhaps thousands, of heart transplants were performed in animals before one such operation was performed in man. And, as early as 1902, surgeons were reporting on attempts to transplant kidneys from one animal to another.

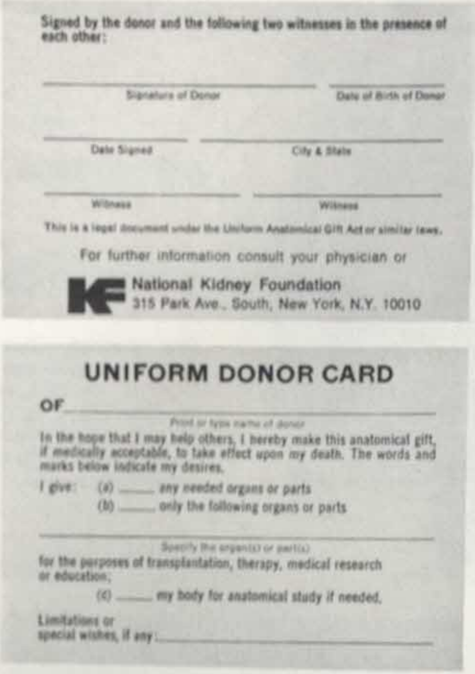
Kidneys. Renal transplants lead all human transplants both in the number done and in the degree of success. More than 3,000 people have received new kidneys. Hundreds of people are alive today who would otherwise have died.

The best results are still obtained when the donor and recipient are members of the same family and have closely matched tissue antigens. In this group of patients the one-year-survival rate is now about 85 per cent. The 1-year-survival rate among patients receiving cadaver organs is approximately 50 per cent. Two-year-survival rates are, respectively, about 77 per cent and 40 per cent.

In many respects the kidney is an ideal organ to transplant. Its blood supply is simple, usually consisting of one artery and one vein. The ureter, which connects the kidney to the bladder, is the organ's only outlet. The lymph system is not necessary for survival; neither is the nerve system. The kidney is easily accessible; it is not surrounded by a bony cage as are the heart and lungs. And if its natural site cannot be used because of a localized disease, the organ can be placed elsewhere. In fact, transplanted kidneys are usually inserted much closer to the bladder than is normal.

If a kidney transplant fails, a second or a third transplant can be done. This is not too successful if the first transplant failed because of rejection. But if the first failure was due to a technical problem, the second transplant is usually a success.

Heart. A historic "first" occurred on December 3, 1967, when Dr. Christiaan N. Barnard, a South African surgeon, performed the first human-to-human heart transplant. The recipient, Louis Washkansky, lived for 18 days before dying of pneumonia. Other such operations were soon performed in a number of countries. Most of the recipients died shortly after the operation, either from infection or rejection. But some enjoyed many extra months of life. Philip Blaiberg, a retired South African dentist who was Dr. Barnard's second heart-transplant patient, lived for 19½



Signed by the donor and the following two witnesses in the presence of each other:

Signature of Donor ______ Date of Birth of Donor ______

Date Signed ______ City & State ______

Witness ______ Witness ______

This is a legal document under the Uniform Anatomical Gift Act or similar laws.

For further information consult your physician or

National Kidney Foundation
315 Park Ave., South, New York, N.Y. 10010

UNIFORM DONOR CARD

OF ______
Print or type name of donor

In the hope that I may help others, I hereby make this anatomical gift, if medically acceptable, to take effect upon my death. The words and marks below indicate my desires.

I give: (a) ____ any needed organs or parts
(b) ____ only the following organs or parts

______
Specify the organ(s) or part(s)

for the purposes of transplantation, therapy, medical research or education;

(c) ____ my body for anatomical study if needed.

Limitations or special wishes, if any: ______

By completing the Uniform Donor Card, any U.S. citizen of sound mind and over 18 years of age may donate all or any part of his or her body to medicine. Individuals under 18 must have their donations authorized by a legal parent or guardian. If the prospective donor changes his or her mind about the donation, all that is necessary is to tear up the card.

months were leading active lives two years after their operations.

The transplant technique used by Dr. Barnard and most other surgeons was devised by Dr. Norman E. Shumway of Stanford University. In this technique the recipient's circulatory and respiratory functions are temporarily taken over by a heart-lung machine. The patient's heart is then removed, leaving only a small piece of the right and left atria. The donor heart is removed in the same manner and is attached to the corresponding parts in the recipient. In addition to the connection at the atria, the new heart must be joined to the recipient's aorta and pulmonary artery.

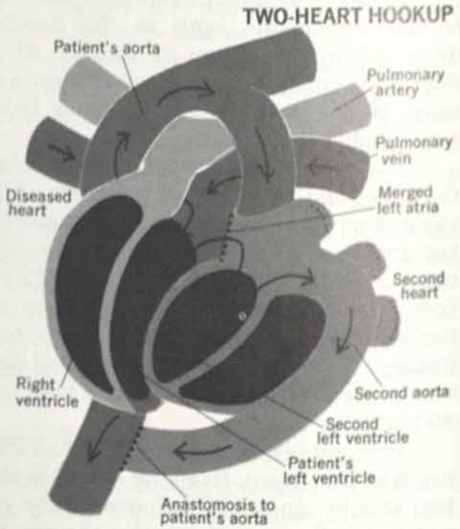
In late 1974 Dr. Barnard performed another experimental transplantation procedure. He implanted a second heart in a patient, leaving the patient's diseased heart in place, and connected the circulation of the two hearts. Heart diseases are a major and increasingly common cause of death. But for the time being, are justifiable only if rigid criteria for recipient selection are met. The patient must clearly be terminal, and all other modes of therapy must have been exhausted. In other words, he must be dying, with a transplant operation his only possible hope for life. In such instances heart transplantation may prolong life and at the same time provide knowledge that will gradually improve results in this area.

Liver. Although heart transplants have been the most dramatic graft operations, they are not the hardest to perform. A liver transplant is much more difficult because the connections of the liver to surrounding structures are much more complex.

Secondly, the liver is very sensitive to interruption of its blood supply. This time between removal from the cadaver and insertion into the recipient must be very short if the liver is to retain its viability.

This diagram shows basically how Dr. Christiaan Barnard connected the circulation of two hearts in parallel. This was the first time the donor heart was sewn to the recipient's heart, giving the patient two hearts working together.

Medical World News



London Daily Express

South African surgeon Dr. Christiaan Barnard has been a pioneer in heart transplant operations.

The liver's functions are extremely varied and complex. It has dozens of vital metabolic functions: making bile, metabolizing and storing foods, producing antibodies, and so on. Deprived of his liver, a human being can live no more than 36 hours.

The first liver-transplant operation in man was performed in 1963 by Dr. Thomas E. Starzl and his colleagues at the University of Denver. Since that time more than 100 such operations have been done. At least seven recipients have lived for more than one year. One patient lived for 29 months after transplantation.

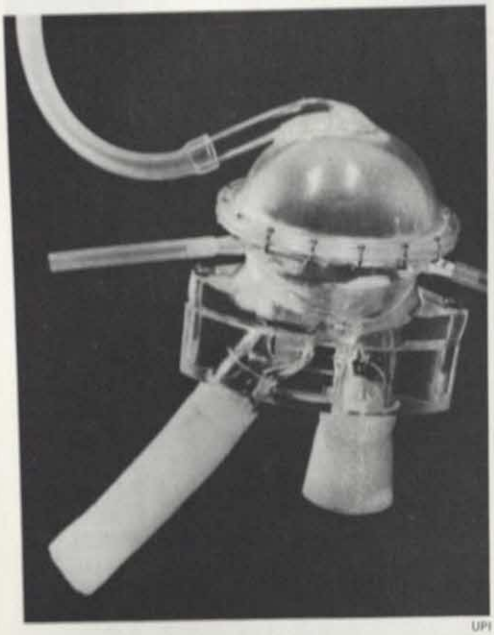
So far these operations have been performed mainly on people suffering from cancer of the liver. However, with increasing experience and success, liver transplants will doubtless be offered to patients with advanced cases of diseases such as cirrhosis and hepatitis.

Lungs. Transplantation of lungs has great potential in treating advanced cases of emphysema, a disease whose incidence has increased alarmingly in recent years.

The surgical techniques involved in replacing a lung are relatively simple. The new organ need only be connected to four large tubes: the pulmonary artery, the two pulmonary veins and the bronchus (the main airway to the lungs). But there are formidable problems—in addition to the ever-present threat of rejection. First, the new organ has no nervous connection with the respiratory center of the brain. This

Hospital Practice—Don Bernstein

The artificial kidney (arrow) is rather large and bulky. It consists of a coil surrounded by a large fluid bath that has a composition similar to human blood plasma. As the patient's blood flows through the coil, waste substances pass from the blood into the bathing fluid.



UPI

Dr. Michael DeBakey of Baylor University used this booster pump to bypass the left ventricle in patients needing temporary cardiac support.

makes it difficult to maintain normal functioning of the lungs. Second, fluids tend to accumulate in the organ. And third, the transplant, like any lung, is continuously exposed to the outside air and the germs it contains. This makes the recipient under immunosuppression very susceptible to infection. In fact, most lung recipients so far have died not of rejection but of severe infections.

THE FIRST LUNG TRANSPLANT IN A HUMAN BEING

The first lung transplant in man was performed in 1963 by Dr. James D. Hardy and his team at the University of Mississippi Medical Center. The diseased lung of a 58-year-old man was replaced with the lung of a man who had died of a heart attack. The transplant functioned normally for the 18 days that the patient lived (he died of preexisting renal disease). By the early 1980's, some 50 people had received lung transplants. With the aid of drugs that help to prevent tissue rejection, several patients have lived for more than a year. Major limiting factors in lung transplantation have been the generally poor health of transplant candidates and the lack of suitable donors.

Eye. Successful transplants of the human cornea have been carried out in thousands of people. Some eye diseases render the cornea opaque, and the individual cannot see well—if at all. By grafting an entire cornea onto an eye that has had the diseased cornea removed, sight can be restored. The cornea homograft is usually one that has been preserved at 4° C for three or four days, or one that has been frozen for three or four weeks at − 196° C. The homograft takes several weeks to heal. Some technical problems may hinder the healing process, but there are no problems with tissue rejection as there are with other organ transplants. Why? The cornea is not in direct contact with the blood vessels supplying the eye.

There have been attempts to graft a living lens from a donor to a living person whose lens has been removed because of disease. Such attempts have been largely unsuccessful because the human lens is extremely delicate. Artificial lenses have been implanted in the place of homografts. These plastic lenses have restored good vision for far distances. But since the plastic lens cannot change shape the way a living lens can, vision at near distances must be aided by spectacles.

Other organs. Transplantation may soon prove valuable for organs other than those discussed above. Dr. Georges Mathe of the University of Paris sees bone-marrow transplants as a potential cure for leukemia. Spleen transplants may give hemophiliacs a chance to lead long, normal lives. Pancreas transplants are being studied as a cure for severe diabetes. This list could, theoretically, include every organ in the body. Yes, even the brain—though few people envision this as ever becoming a reality.

In addition to homografts, there are two other possible replacements for diseased organs: heterografts and artificial organs.

THE POTENTIAL OF HETEROGRAFTS

The first transplant in man was actually performed four years before Dr. Barnard did his famous operation. It was a heterograft: Dr. Hardy and his colleagues transplanted a chimpanzee heart into a 68-year-old man (they had planned to use a human-donor heart, but none was immediately available). Although the patient died soon after the operation, it did demonstrate that the organ could be easily preserved and transplanted, and that it could support the man's blood pressure.

A few kidneys from baboons and chimpanzees have also been transplanted into humans. Several of the chimpanzee organs functioned surprisingly well.

If heterograft operations can be perfected, they will greatly increase the number of organs available for use in human beings. But the problems are more formidable.

At the present time, transplantation of lower-primate organs into man is rarely attempted.

MAINTAINING LIFE WITH MAN-MADE DEVICES

During the past two decades bioengineers have developed a number of artificial substitutes for diseased tissues and organs. Some of these, such as *kidney dialyzers*, are external devices. Others, such as plastic heart valves and artificial blood vessels, are implanted in the body, replacing the diseased or damaged part. Two devices are of special interest: the dialyzer, because of its great success, and the artificial heart, because of its great potential.

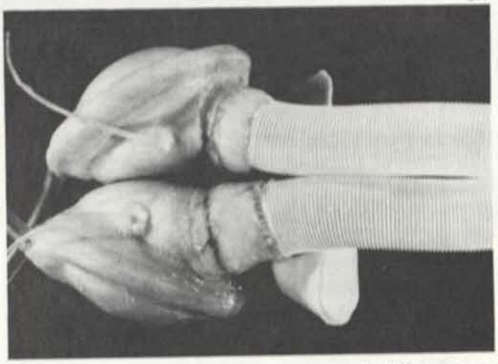
Artificial kidneys. The major function of kidneys is to remove wastes from the blood. The artificial kidney, or dialyzer, performs this function for a person whose kidneys do not work properly. Approximately twice a week, for several hours at a time, the patient's blood supply is connected to the machine via an artery in his arm or leg. The blood passes from this body into the tubes of the machine. Wastes pass through the walls of the tubes, and the cleansed blood flows back into a vein in the patient's body.

Patients awaiting kidney transplants are often maintained on dialyzers until organs become available. Some patients with nonfunctioning kidneys cannot, for one reason or another, receive kidney transplants. They can be kept alive for years on these machines.

Artificial hearts. In April 1969, Dr. Denton A. Cooley of St Luke's Episcopal Hospital in Houston, Texas, performed a

Below: the artificial human heart shown here was used by Dr. Cooley in the first total replacement of a human heart by a mechanical device. Bottom: this experimental artificial human heart was developed at the University of Utah by Dr. Clifford S. Kwan-Gett.

UPI



University of Utah Medical Center

NIH/Science Source/Photo Researchers

The Jarvik artificial heart, like the one implanted in the chest of Barney Clark, is powered by air compressed by an external electric pump mounted on a movable table.

very controversial operation. He placed a Dacron and Silastic heart into a dying man. Three days later a cadaver heart became available and was used to replace the artificial device. The next day the patient died, primarily of pneumonia and kidney failure.

Some 13 years later, at the University of Utah Medical Center, an artificial heart powered by a 170-kilogram external system was implanted in the chest of 62-year-old Barney Clark. He died 112 days later of multiple organ collapse. The heart, still in perfect working order, had pumped regularly almost 13 million times. Experts believe that even better hearts can be built, with their own implantable motors. But because of the very high costs and risks associated with continuous reliance on a mechanical heart, many authorities see its best use to be in sustaining a patient until a donor heart can be inserted.

THE FUTURE: DOCTORS ARE OPTIMISTIC

Today many people are living relatively normal lives thanks to transplant operations. Such operations are becoming common occurrences. In the case of kidneys, the procedure is no longer considered to be experimental; rather, it is an accepted method of treating chronic kidney failure. Results being obtained in other transplant operations are improving.

Of course, certain problems must first be solved. Foremost among these is the rejection-infection phenomenon. Then there is the problem of maintaining the organs between the time they are removed from the cadaver and the time they are placed in the recipient. There is the problem of not enough donor organs—and the problem of closely matching these to waiting recipients. But, as Dr. C. Walton Lillehei, a surgeon at New York Hospital, has said: "You just can't venture into a wilderness and expect to find a paved road. All these problems are soluble—in time."

Dr. Lowell T. Harmison of the National Institute of Health Artificial Heart Program examines a calf that has a totally implanted artificial heart-assist system with internal power and automatic controls.

National Heart and Lung Institute

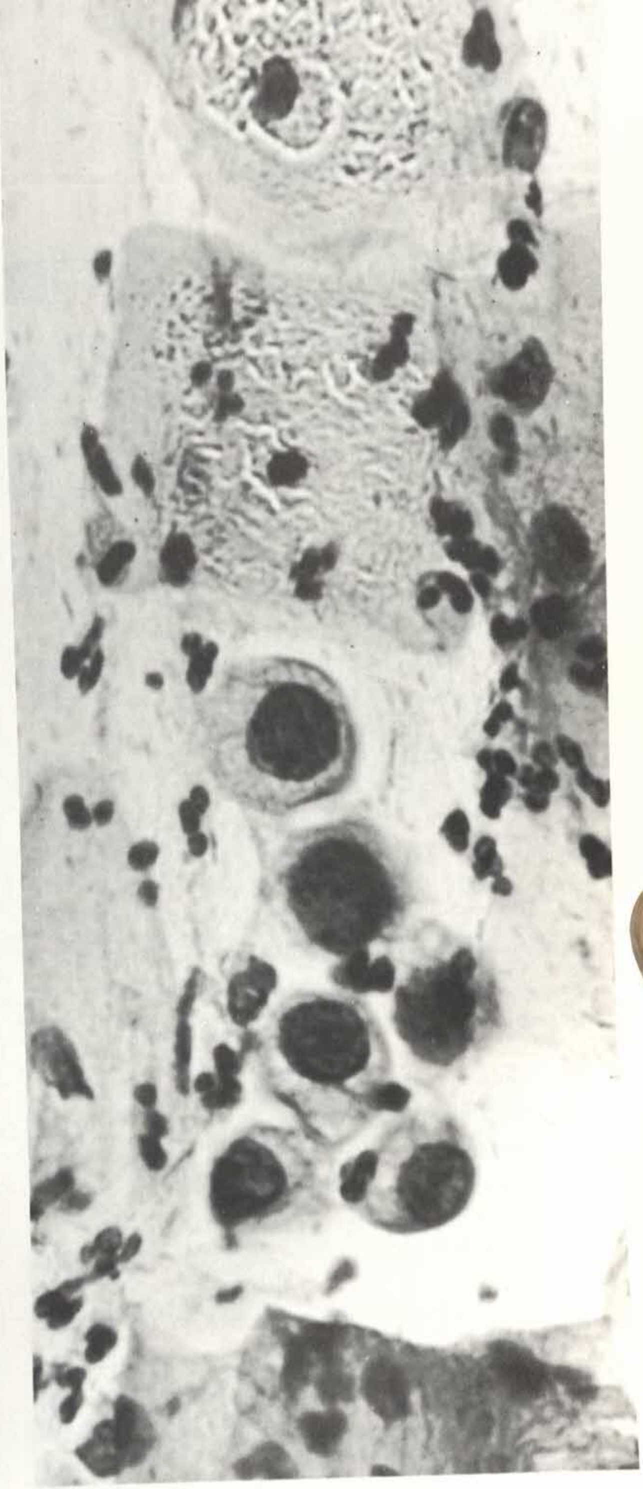
CANCER

A cancer is a *tumor*—a growth or enlargement of the tissues. But not all tumors by any means are cancerous. Actually, they are divided into two general classes: *malignant* and *benign*. A *malignant tumor* grows rapidly or slowly, and spreads from the place in which it started to other parts of the body, nearby or remote. A cancer is a malignant tumor. A *benign tumor* is confined to the area in which it originated. Its growth is usually slow. The term benign is somewhat misleading, since a benign tumor may do harm. It would be better to refer to tumors of this type as nonmalignant.

People sometimes use the word cancer in the singular to refer to malignant growths in general, as if a single specific disease were involved. It is more accurate to refer to the *cancers*—a group of diseases that have certain features in common but that may differ widely in other respects. However, the use of cancer in the sense of cancers still persists.

There has been a steady increase in the number of known cancer cases in the last generation. The cancers now cause the second-largest number of deaths in the United States and in most countries where statistical records are well kept. In the United States, it is estimated that one out of every four persons will eventually have a malignant tumor. In children, the cancers are the leading cause of death, not including accidents.

There are various reasons why the cancers appear to be on the increase. For one thing, though their victims are to be found in all age groups, they are particularly apt to attack persons in their middle and advanced years. Naturally, since people live longer these days, there are more cancer victims than formerly. Again, with better methods of diagnosis, doctors can more readily recognize cancerous growths that would formerly have passed unnoticed or that would have been wrongly diagnosed. It is believed, too, that certain habits and conditions of modern living, including heavy smoking and the pollution of the air, may expose people to more cancer-causing circumstances than before.



Malignant cells (near the center of the photo) have enlarged, darkened nuclei and little cytoplasm. Above these are two normal cells with large masses of cytoplasm and small nuclei.

FALLACIES AND FACTS ABOUT CANCERS

Will eating hot foods cause a cancer?	No
Will using aluminum cooking utensils cause a cancer to develop?	No
Is there any evidence that irregularity of eating or drinking causes cancer of the stomach?	No
Can a cancer be caused by a bruise or injury? Note: Not from a single injury.	No?
Could one get a cancer from physical contact (such as kissing) with a person who has cancer?	No
Could an animal with a cancer pass it on to a person who touched it?	No
Will eating meat from an animal who had a cancer cause a cancer to develop in a human being?	No
Do hemorrhoids ever turn into a cancer? Note: They may hide a cancer and should always be brought to the attention of the physician.	No
Do corns or calluses ever turn into a cancer?	No
Can one's mental condition have any influence on the development of a cancer? Note: Anyone can develop a cancer.	No?
Is it true that cancers usually develop in persons with poor health?	No
Once cured of a cancer, can you develop another cancer?	Yes
In the same place?	Yes
In some other part of the body?	Yes
Can a person with tuberculosis develop a cancer? Note: It has been suggested, but not proved.	Yes

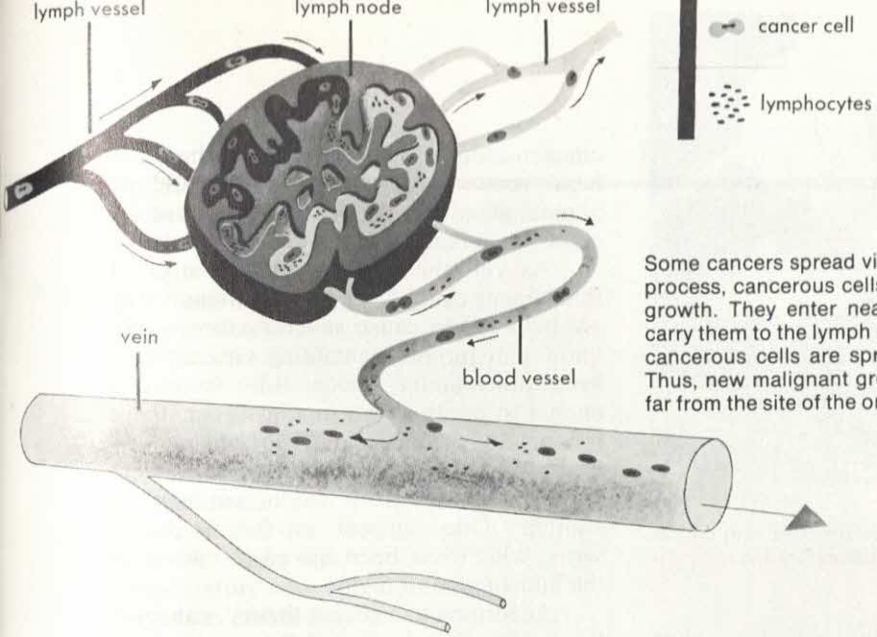
CANCEROUS GROWTHS

Growth is a normal characteristic of the human body, as it is of living things in general. The body develops from a single cell that has been fertilized. This cell divides into two. The two cells divide into four, and so on, until a little ball is formed. The differentiation of cells into various tissues then begins. The normal human being develops until he is mature, and then he stops growing. Only when there is an injury is growth resumed, and then only to the point of normal healing. New cells are constantly being formed in the skin and other places, it is true, but these cells simply replace those that have died.

Cancers represent wild and uncontrolled growths of cells, which form a highly erratic pattern. These cells resemble somewhat the noncancerous cells in a given tissue, but there are marked differences. Cancerous cells have a more primitive appearance. They are quite irregular in shape and have large and irregular nuclei. They carry out few or none of the functions of normal adult cells. They are most likely to develop, in the case of men, in the skin, lungs, prostate gland, stomach, and intestines. In women, the commonest sites are the breast, uterus, intestines, skin, and stomach.

Normal cells may be completely replaced by tumor cells. Cancerous cells tend to invade surrounding tissues. They may even break off from the parent growth and migrate through the blood or lymph circulation to other parts of the body, perhaps far from the original site. Here they start new malignant growths. This process of cancer spread within the body is called *metastasis*.

As they continue to grow in uncontrolled fashion, malignant tumors become a menace to life. They interfere with bodily function. The pressures that they create produce severe pain when nerves are affected. Malnutrition goes hand in hand with cancerous growth. The cancerous tissue seems to draw to itself the nutrients taken into the body. Normal tissues are deprived of their fair share of these nutrients.



Some cancers spread via the lymph system. In this process, cancerous cells break off from the parent growth. They enter nearby lymph vessels, which carry them to the lymph nodes. From the nodes, the cancerous cells are spread throughout the body. Thus, new malignant growths are set up in organs far from the site of the original tumor.

TYPES OF CANCERS

Various cancers cause various signs and symptoms, or changes in function, according to the kind of tissue or body part involved. For example, a cancer of the pituitary gland, or *hypophysis,* may cause abnormal growth, and the victim may become a dwarf or a giant. When the pancreas is affected, there are often digestive disturbances and diabetic symptoms. In the brain and spinal cord, a malignant growth sometime causes paralysis. Some cancers can erode blood vessels and cause sudden death by hemorrhage.

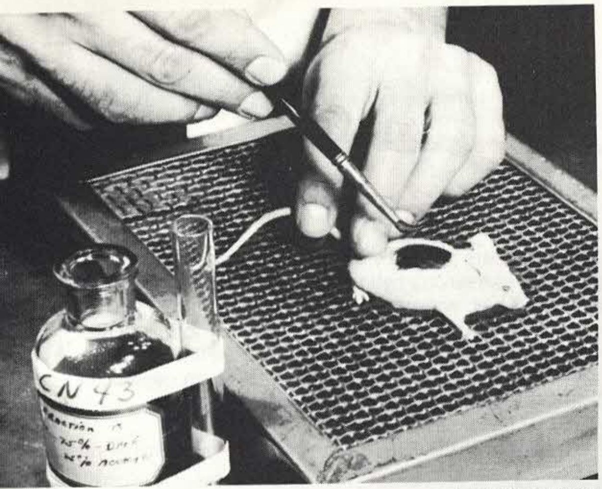
Physicians classify cancers according to the tissues in which they originate. We can list only a few representative types here. The *carcinomas* arise from the cells of the skin, the lining membranes of internal organs, and the glandular organs. The *sarcomas* develop in muscles, bones, cartilages, and connective tissues. Cancers originating in the network of supporting connective tissues in the brain and central nervous system are called *gliomas*. A particularly dangerous type of cancerous growth is the *melanoma*. This is a rapidly growing pigmented tumor. It originates in certain types of pigmented moles found on the skin. If these moles are irritated, they may become malignant, and the resulting cancers metastasize rapidly.

The lymph nodes and other tissues of the lymphatic system give rise to cancerous growths called *lymphomas*. The condition known as *Hodgkin's disease* is now recognized as a lymphoma. It was formerly regarded as an infectious disease. Another lymphoma is *lymphatic leukemia*. It is marked by enlargement of the lymph nodes. The white-cell-forming centers in these nodes become unduly active, and the number of white cells becomes abnormally great. The liver and spleen are enlarged. An acute form of anemia sets in.

CAUSES AND CONTRIBUTING FACTORS

In the present state of our knowledge, it is still not clear just what causes a cancer. However, there are certain more-or-less well-established contributing factors. These include environmental agents (chemicals, radiation), the genetic background of the individual, gross chromosomal abnormalities, hormonal dysfunctions, and viruses.

Most theories of how cancer is caused at the molecular level focus on events that might occur in DNA (the genetic material) to lead to a breakdown in the growth-control of cells, resulting in the formation of cells with malignant behavior. Such events include alterations in genetic material, or the addition of new material by viruses, or simply the activation of normal genes that



American Cancer Society

Tars found in cigarettes will produce skin cancer when applied to the skin of laboratory mice.

are always present but not active, as when embryonic genes become "turned on" in some specific liver cancers in adult humans.

Some cancers may arise as the result of a two-step process; the steps could be separated by years. The first step, initiation, involves a permanent change, such as a mutation, while the second step, promotion, involves an irritation that causes the initiated cells to divide. Some substances in the environment are initiators and some are promoters.

There are several examples of how chronic irritation predisposes to cancer. Cancers of the lip may occur when tobacco pipes are smoked. Irritation due to broken or malformed teeth has often led to cancer of the tongue or cheek. People who have been exposed for many years to sun and wind have developed cancers of the skin. We should point out, however, that a great many people experience chronic irritations of various kinds without developing malignant growths. It would appear, therefore, that irritation by itself would not suffice to cause cancer. There must also be something in the tissues that increases the likelihood of malignancy.

The theory of irritation through hormones has been advanced. It seems clear that there is a relationship between hormones and cancer. According to studies, if rats are given high levels of specific hormones, they have an increased rate of carcinogen-induced liver cancer. On the other hand, removal of the pituitary, thyroid, or adrenal glands prevents a variety of carcinogens from inducing liver cancer in rats.

As yet, there is no conclusive proof that *viruses* cause all cancers, although they are believed to cause several cancers. We know that tumors containing viruses have been transplanted successfully from one animal to another. So far, however, there is no real evidence that viruses or any other infectious agents can cause cancers to be transmitted from one human being to another. One suspect is the *herpes 2* virus, which has been linked to cancer in the human genital region.

According to a recent theory, cancer is the result of viral genes that were incorporated into the host species' genes long before. These pieces of viral gene sit quietly on chromosomes and are passed on from generation to generation. At some point, however, these so-called *oncogenes* are activated by chemicals, radiation, or other means.

Viral particles have been identified in human tumors, such as Burkitt's lymphoma, often on the same chromosome as immunoglobulin genes. It is proposed that whatever activates the immunoglobulin genes also activates the cancer-producing oncogene in the same way.

More and more cancer researchers are pointing an accusatory finger at the environment. They believe that most human cancers are, in part, caused by exposure to cancer-causing substances in the environment. These include naturally occurring agents in our diets, air, and sunlight, in addition to man-made substances.

There is much controversy over the role of *atmospheric pollution* as a cause of cancers. It is true that these diseases are more apt to strike city dwellers than country dwellers. It is also true that the atmosphere over cities is often seriously polluted with the products of combustion of coal and oil, with the gases arising from various chemical processes, with motor-exhaust gases, with a heavy blanket of soot. The increase in industrialization runs virtually parallel with the increase in lung cancer cases. Yet we cannot say that there is necessarily a cause-and-effect relationship here, since many other factors are involved.

Statistical studies in the United States and elsewhere leave not the slightest doubt that heavy *smoking* of cigarettes is associated with the increase in the number of lung cancer cases. There is as yet no positive evidence that cigarette smoking alone causes lung cancer. However, the statistics are disturbing, to say the least.

It is well known that excessive *radiation* will cause cancerous growths. Early investigators who used X rays without appropriate shielding and other protective devices often fell victim to the radiation, and some of them developed cancers. In recent years, more and more attention has been drawn to radiation as a cause of malignant growths, what with weapons based on nuclear fission and the increasing use of radioactive substances in medicine and in industry.

Careful studies have been made of the amount of radiation that an individual can endure without running into danger. The safety margin is not so great as was formerly believed. The average person can withstand only a limited amount of radiation in a lifetime. Cosmic rays, to which we are all exposed, account for some of it. A certain amount of radiation stems from medical and dental X rays. More may come from radioactive fallout resulting from the setting off of atomic bombs or from the escape of radioactive materials into the community from industrial establishments or wastes.

The association between skin cancer and sunlight has been known since the early 1900's. Ultraviolet radiation in sunlight is absorbed mainly by the skin. In humans the incidence of skin cancer is related to exposure to sunlight and intensity of solar radiation. Care to avoid overexposure to this cancer-causing agent is important.

Chemical substances added to food or used in the manufacture of products may have some bearing on the development of cancers. Substances believed to produce cancer are known as *carcinogens*.

Many chemicals, some used widely in industry, are suspected or known carcinogens. One such compound is vinyl chloride, which is widely used in the plastics industry and is suspected of causing a rare type of liver cancer. Benzene, a very common compound, is suspected of causing leukemia. TRIS, a chemical used to make children's clothing fire retardant, is also a suspected carcinogen.

Some inorganic compounds are also suspected culprits. Inorganic arsenic compounds, used in the pesticide industry, have been linked to cancer-caused deaths among industry workers. Asbestos, used as an insulating compound, is known to cause a type of lung cancer called *asbestosis*. Fine particles of silica dust, the products of foundry operations, are responsible for *silicosis*, another lung cancer.

Federal law in the United States requires that any substance that is shown to cause malignancy in animals must be excluded from human foodstuffs and cosmetics. With this in mind, researchers are now making extensive studies on many substances used in the preservation, coloring, flavoring, conditioning and preparation of foodstuffs.

There are also naturally occurring chemical substances in foods that are carcinogenic. Examples include nitrites, nitrates, and nitrosamines, the consumption of which may be related to stomach and esophageal cancer. It is important not to be frightened of foods naturally containing these substances, but to avoid eating excessive amounts of them.

In addition, other naturally occurring chemicals in foods seem to act as anticarcinogens. In the future, after more research, careful planning of diets to delete carcinogenic compounds and include anticarcinogens may be an important strategy in minimizing some cancer diseases.

What of heredity? Is a person more likely to develop a cancer if other members of his or her family have been cancer victims? There are at least 14 cancers that are clearly inherited. For example, a cancer of the eye called retinoblastoma is a hereditary tumor.

Some of these cancers involve a genetic predisposition toward the disease, and the cancer is expressed after the person is exposed to a specific environmental agent. For example, a genetic disorder called xeroderma pigmentosum predisposes a person to skin cancer because it prevents the repair of genetic material damaged by the ultraviolet radiation in sunlight. This damage can cause skin cancer.

According to one theory, a family with a genetic tendency toward developing cancer may have more cancer-producing oncogenes and genes that are more easily activated than do other families.

DIAGNOSIS

We cannot at present prevent the formation of malignant growths. It is extremely important, therefore, to detect a malignant condition at the earliest possible stage. We should be on the lookout for precancerous growths—growths that may ultimately develop into cancers. For example, there may be a change in the mucous membrane covering the tongue or lining the mouth cavity, causing a patchy appearance—a condition known as *leukoplakia,* or white patches. It is very definitely a precancerous condition. The person in whom it appears should not only consult a doctor but should at once give up the use of tobacco. Persistence of sore places in the mouth or on the lips is potentially precancerous. In older persons, a small sore may develop on the skin, heal, and then come back. Such sores should not be neglected, because they may be and often are precancerous. In some cases, precancerous growths rapidly develop into cancers. In other cases, as much as ten years may elapse before the growths become malignant. Sometimes they never become cancerous.

Dr. George Papanicolaou, developer of the Pap test. The Pap test is a simple, painless procedure for detecting cancer in its early stages in various organs.

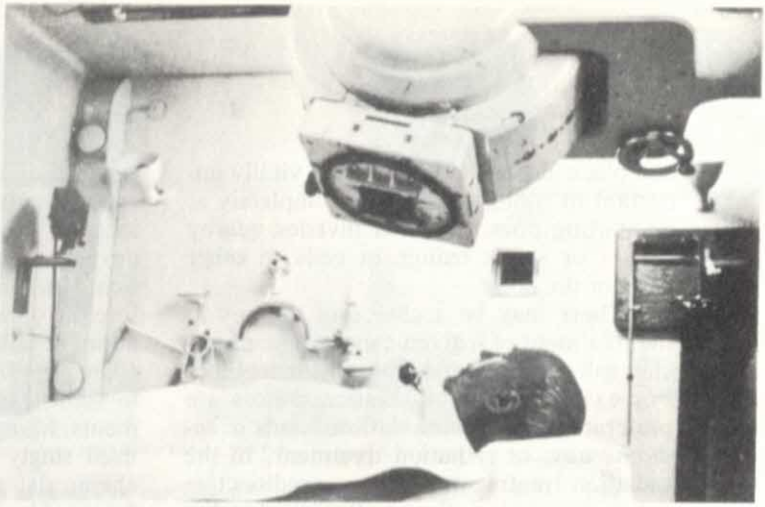
American Cancer Society

The American Cancer Society has given wide publicity to the symptoms that may indicate precancerous or cancerous growths. Here is a list of these symptoms:

1. Unusual bleeding or discharge.
2. A lump or thickening in the breast or elsewhere.
3. A sore that does not heal.
4. Change in bowel or bladder habits.
5. Hoarseness or cough.
6. Indigestion or difficulty in swallowing.
7. Change in size or color of a wart or mole.

If a person has any of these symptoms only once, there is no reason to be alarmed. However, if they persist or keep coming back, it is time to consult a physician.

It will be easy for the physician to recognize certain types of cancers that can be seen or felt. In other cases, various tested methods of diagnosis will be used. Diagnostic methods in the detection of cancer will vary according to type and location of suspected cancer tissues. For example, *transilluminating,* or shining light through, breast tissues may reveal opaque masses that can later be further explored by *palpation,* or feeling with the hands, and



Applying radiation treatment for cancer at the Karolinska Hospital in Stockholm, Sweden. A beam of radiation is focused on a malignant tumor. Such therapy is effective in eradicating or retarding some types of localized cancer.

Jean Mohr, WHO

biopsy. The most reliable is the technique known as biopsy, which consists of a microscopic examination of a small portion of the suspected cancer. In some cases, such as those involving growths on the breast, the biopsy can be performed quickly. After an incision is made, a small bit of tissue is removed from the suspected area. It is frozen and examined under the microscope while the patient is in the operating room. If the report indicates that the growth is cancerous, the surgeon proceeds with the necessary operation. If the report is negative, he merely removes the tumor.

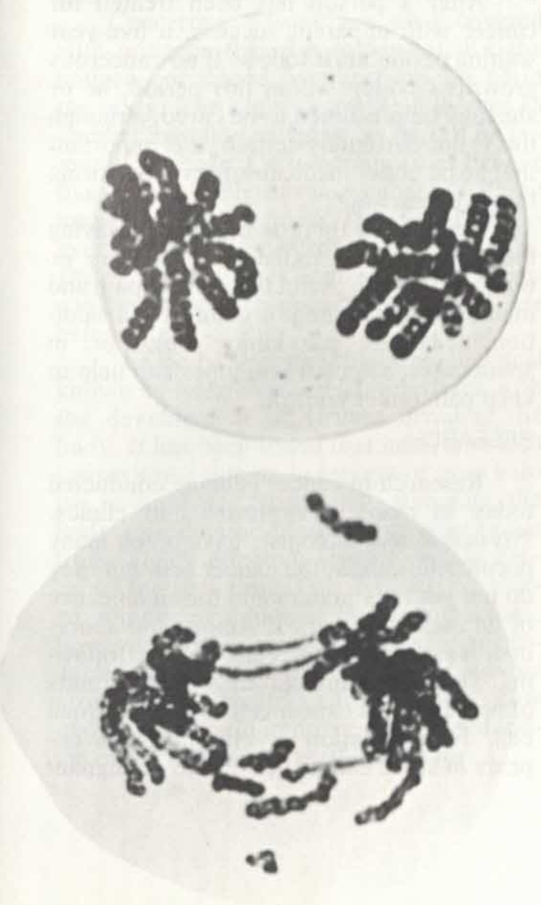
The so-called *Papanicolaou technique*, or "Pap" test, is used in examining secretions from the lung, stomach, mouth, intestines, bladder, and, most commonly, the cervix and uterus. It is based on the fact that malignant growths on the surface of internal organs shed their cells into the secretions from these organs. The cells can then be identified under the microscope. X rays are also a valuable means of diagnosis, particularly in cases involving the digestive tract, kidneys, and chest.

TREATMENT

There was a time when a diagnosis of cancer was equivalent to a sentence of death after prolonged suffering. Today one-third of all persons with cancers can be cured. This number could be increased to one-half the total number of cases if more people paid attention to the warning signs and procured medical treatment promptly.

All cancers start at some definite location in the body, and few start in more than

Brookhaven National Laboratory



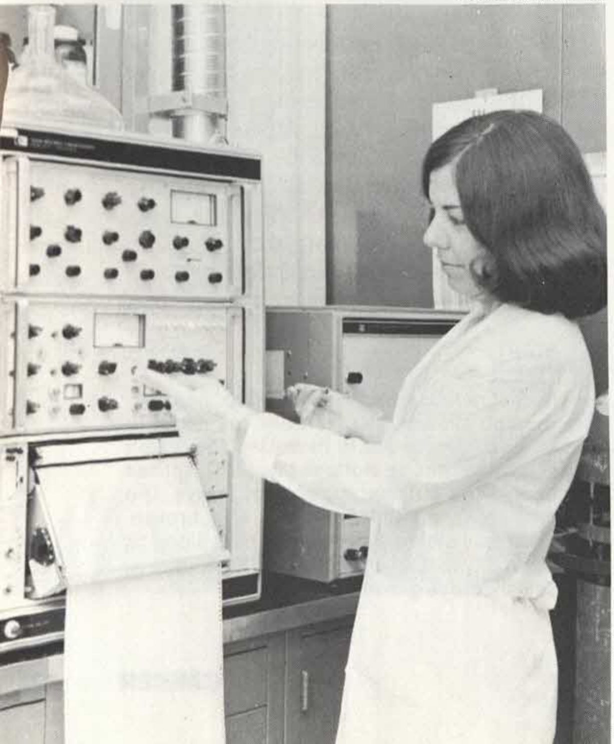
The effect of radiation on living cells. Top: this photomicrograph shows a normal plant cell about to divide. The chromosomes in its nucleus have split into two similar groups. Bottom: this plant cell has been exposed to a damaging dose of X rays. The chromosomes are tangled, frayed, and broken. Such a cell may die or, if it lives, may pass along its altered heredity to future generations. It might even produce cancerous growths.

one place at the same time. It is vitally important to root out a cancer completely at its starting point before it invades nearby tissues or sends malignant cells to other parts of the body.

There may be a choice of therapy in the treatment of a given cancer. The physician will select the most promising method. For example, some malignant tumors are preferably treated with various kinds of *radiotherapy,* or radiation treatment. In the radiation treatment, X rays or radioactive substances are employed. Beams of radiation are focused on the tumor, killing the cancer cells. In some cases, minute particles of radioactive material are inserted directly into the cancerous tumor, so that the radiation reaches the tumor cells without having to pass through normal tissues. Others respond to drug treatment, although, at present, there is seldom any permanent cure to be obtained with drugs. Surgery is preferred if it is at all possible. The surgery, which may be extensive, involves completely removing the cancerous growth. Whether surgery alone will be recommended, or radiation alone, or a combination of surgery and radiation will depend on the location of the tumor, the stage of its development, and the condition of the patient. In some cases, radiation is used before the operation; in others, after the operation; in still others, both before and after. *Chemotherapy,* or drug treatment, is used in some cases to supplement other treatments. Many different chemicals have been used singly or in combination with other chemicals, as in the treatment of certain forms of leukemia.

A technician at the U.S. National Cancer Institute uses a gas chromatograph to analyze a compound suspected of being carcinogenic.

National Cancer Institute



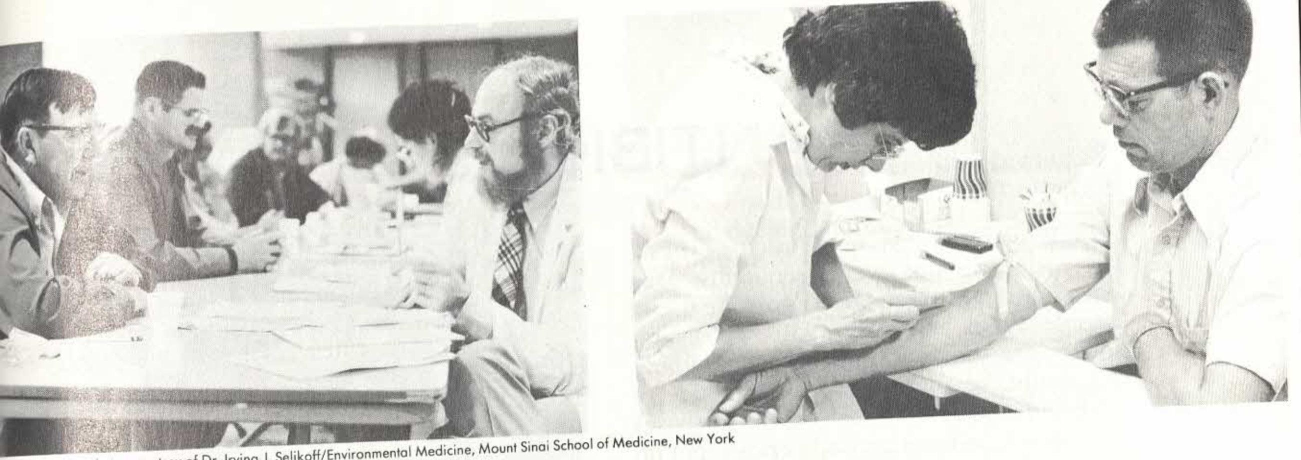
Some tumors are hormone-dependent, that is, they change in size as certain hormone levels are altered. Cancer of the prostate in males can be checked by means of female hormones. Breast cancers in females are controllable to a certain extent by the male hormone. The tumor cells, however, often lose their dependence on hormones as time passes, so hormonal approaches to cancer treatment have yielded variable results.

After a person has been treated for cancer with apparent success, a five-year waiting period must follow. If no cancerous growths develop within this period, he or she may be presumed to be cured, although this is not absolutely certain. It is important that he be under medical supervision during this five-year wait.

Even when there is no hope of saving the patient's life, radiation or surgery or both may still be useful in relieving pain and increasing the patient's comfort. In addition, sedatives, pain-killing drugs, or, in some cases, selected hormones can help to keep pain under control.

RESEARCH

Research in cancer is being conducted today in many laboratories and clinics. Physicians and biologists have noted many peculiarities about the cancer cell, but they do not yet fully understand the significance of all their discoveries. Among the abnormalities of cancerous cells are the following. There are more chromosomes, or units of heredity, in a cancer cell than in a normal cell. Fragmentation of chromosomes appears in some cancer cells. Also, malignant



photos courtesy of Dr. Irving J. Selikoff/Environmental Medicine, Mount Sinai School of Medicine, New York

There is growing concern over the presence of carcinogenic compounds in industrial processes. Vinyl chloride has been linked to a rare form of liver cancer. Here, workers who have been exposed to the compound are screened for the cancer. Vinyl chloride is only one of many known or suspected carcinogens that are common in industry.

cells are interconnected by very thin strands of protoplasm. Another phenomenon displayed by cancer cells is that they can be most dangerous when they are disintegrating. When they do so, they release harmful substances that damage the organs and tissues of the body.

Cancerous tissues are also covered with antigens that are somewhat like the antigens produced by infectious germs in the body. The body secretes antibodies to combat invading antigens, as part of its immunity defense. Certain authorities believe that some people develop cancers without knowing that they do so. The cancers, however, are rapidly destroyed by antibodies. Drugs and vaccines that stimulate a person's immune responses to cancer are being sought.

The body also secretes a biochemical known as *interferon*, which interferes with the development of viruses invading the body. It has been found that interferon also causes some tumors to regress or even vanish in animals. Drugs that stimulate the body's production of interferon may prove to be highly effective against certain cancers. One such drug, Poly-I-C, has combatted tumors in animals. Some authorities, however, do not think that interferon production is the real solution to the cancer problem in humans. Clinical trials now under way should improve our understanding of the effectiveness of interferon.

Another class of body secretions is the so-called *chalones*, which are normally present and prevent many kinds of regular body cells from multiplying much of the time. Tumor cells have been found to be low in chalones, while otherwise-normal cells near the site of the malignancy are high in chalones. Experimental injection of chalones into cancerous laboratory animals causes certain tumors to decrease or even disappear.

Cancer cells are actually more susceptible to drug action when they are growing and multiplying. Certain drugs may be very potent in attacking cancer cells during growth. For example, the drug L-asparaginase stops the spread of leukemia (blood-cell cancer) by destroying certain chemical foodstuffs needed by growing leukemia cells. L-asparaginase is undergoing clinical tests on human patients at present.

The early detection of cancer is vital for its cure. Simpler and surer tests for cancer are being sought, especially those based on blood and urine sampling. A recent blood test has revealed the presence of intestinal cancer very precisely in humans.

There is no reason to believe that researchers will not eventually be successful in finding cures for cancers. In the meantime, the terrible toll that cancers take would drop significantly if people learned to recognize the symptoms and consulted a doctor as soon as possible.

ANTIBIOTICS

"Wonder drugs." "Miracle drugs." These descriptions were frequently used when antibiotics first came into wide use in the late 1940s and early 1950s. Exaggerations? Yes, but antibiotics have, without any doubt, revolutionized the practice of medicine throughout the world. Diseases that once killed and caused serious and often long-lasting illness can now very often be treated successfully. Among these diseases are pneumonia, typhoid, scarlet fever, tuberculosis, and many other infections caused by bacteria, fungi, and other microorganisms.

Antibiotics have also had great impact on veterinary medicine, animal nutrition, and the preparation and preservation of foodstuffs.

WHAT ARE THEY?

Antibiotics are chemical substances that can inhibit the growth of or in some cases destroy bacteria and some other microorganisms. The antibiotics themselves are produced by living organisms, such as molds and bacteria. If a product of a living organism is found to have antibiotic properties, it is cultured. The antibiotic is isolated and means for producing it in large quantities are devised.

There are now more than 80 known antibiotics. Each antibiotic does not have an effect against all bacteria, however. Rather, antibiotics are selective. Each antibiotic is effective against just some microorganisms – a specific spectrum or range – and generally not against others not in that spectrum. Some are effective against a large range of microorganisms; these antibiotics are known as *broad-spectrum antibiotics*.

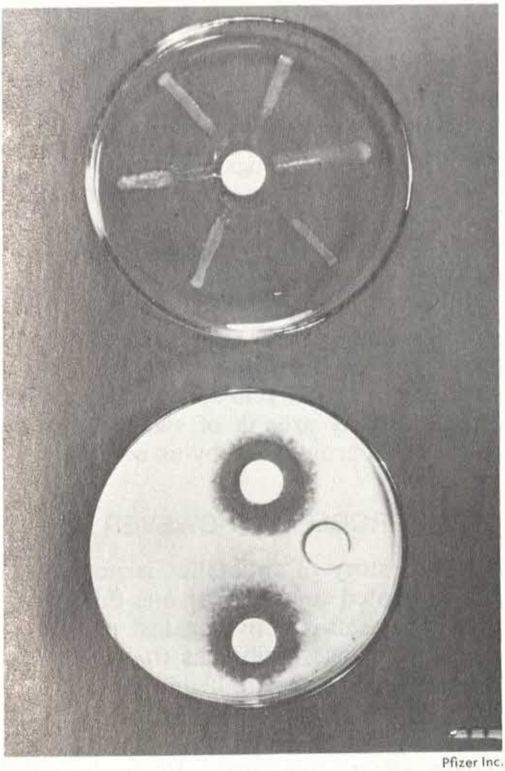
HOW THEY WORK

There are basically two types of antibiotic action: *bacteriostatic action* and *bactericidal*, or *bacteriolytic*, action. Antibiotics that are bacteriostatic inhibit the growth of sensitive organisms without actually destroying them. Bactericidal antibiotics kill the sensitive organisms by interfering with one or other of their biochemical functions.

Some bactericides, such as penicillin and bacitracin, block the synthesis of bacterial cell walls. Others, including polymyxin and novobiocin, combine with the microorganism's cell membrane and block the passage of nutrients and waste products, while another – tyrocidin – actually destroys the cell membrane. Antibiotics such as erythromycin and the tetracyclines block protein synthesis in the bacterial cell. Still others block nucleic acid synthesis and the binding of vital trace elements. With important biochemical functions turned off in the bacte-

Molds that have potential for use as antibiotics are first isolated and then incubated in a test tube. This test tube holds a colony of *Streptomyces rimosis*. Spores from this colony will be used to produce larger quantities of the mold.

Pfizer Inc.



Pfizer Inc.

Testing for antibiotic power. If the disks containing mold fluids inhibit germ growth around their margins, then they have antibiotic power against that specific germ.

ria, the microorganism is no longer able to damage normal cells and produce disease.

THE FIRST ANTIBIOTICS

The first antibiotic to be used in treating human disease was tyrothrycin, derived from *Bacillus brevis,* a soil bacterium, and isolated by René Dubos of the Rockefeller Institute for Medical Research (now Rockefeller University) in New York City. Tyrothrycin is still used, but on a very modest scale, since it is highly toxic. It serves only in treating infections on the surface of the body.

The first of the antibiotics to attract worldwide attention was penicillin, an acid produced by the mold *Penicillium notatum.* A British scientist, Sir Alexander Fleming, discovered in 1928 that his cultures of bacteria would not grow in the presence of this mold. He found that the mold produced a substance – penicillin – that was toxic to various disease-causing organisms. Fleming did not carry forward his investigation of penicillin, and his epoch-making discovery was all but forgotten.

Several years later Sir Howard W. Florey, Ernst Boris Chain, and others in England decided to investigate the possibilities of pencillin in the treatment of various infections. In 1941, the drug was first administered to human beings, with amazingly successful results. In the summer of that year Florey came to the United States to seek help in producing penicillin in quantity. This goal was achieved by the following year through the efforts of the U.S. drug industry and the U.S. Department of Agriculture's Northern Regional Research Laboratory. Penicillin was employed extensively in the 1940s to prevent infection of wounds sustained during wartime and it saved many lives. Since that time many thousands of millions of units have been used in the treatment of disease.

Penicillin is generally given by injection. It is given by mouth in some cases. It is active chiefly against *gram-positive bacteria.* This name is given to bacteria that hold a purple dye when stained by a method developed by the Danish physician Hans C. J. Gram. These bacteria include the streptococci and the staphylococci.

Bacteria that do not hold the dye when stained by Gram's method are called *gram-negative.* Penicillin is not effective when used against most gram-negative bacteria or the tiny bacterialike organisms called rickettsiae. Penicillin is useful in the treatment of bronchitis, meningitis, osteomyelitis, tonsilitis, tetanus, and various other diseases. It also combats infection in burns and wounds.

NEWER ANTIBIOTICS

Another important antibiotic is streptomycin. It is derived from *Streptomyces griseus,* a microorganism growing in the soil. Streptomycin was isolated in 1943 by Selman A. Waksman and his assistant Albert Schatz at Rutgers University. It was first used on human beings in 1945. It is particularly effective in treating tuberculosis. It has been used to combat meningitis, peritonitis, abscesses of the liver, and infections of the urinary tract and lungs. Streptomycin is much more toxic than penicillin. It

Testing antibiotics on cultures containing microbes.

sometimes produces certain unfortunate side reactions. The antibiotic called dihydrostreptomycin, derived from streptomycin, is less toxic.

Broad-spectrum antibiotics include terramycin and aureomycin. Terramycin has been employed with considerable success in the treatment of tuberculosis.

Neomycin has been used to combat infections of the skin, eyes, and intestinal tract. Viomycin has been added to the drugs used in fighting tuberculosis. It has been found valuable in treating tuberculous patients who have developed resistance to other drugs, such as streptomycin and isoniazid. Bacitracin is sometimes the best drug for wound and postoperative infections. Its internal use is limited, since it may damage the kidneys.

USE IN ANIMAL MEDICINE AND NUTRITION

The antibiotics have also proved their worth in animal medicine. They have saved the lives of thousands of animals. They have revolutionized animal nutrition, for it has been found that they have an extraordinary effect on animal growth. Small quantities of terramycin, penicillin, and other antibiotics are often added to livestock feeds. They bring hogs, chickens, turkeys, and other livestock to market weight weeks sooner than before.

Researchers have discovered that the antibiotics offer a promising means of controlling halo blight of beans, fire blight of apples and peaches, and other crop diseases. It has been found, too, that small amounts of terramycin speed the germination and early growth of sweet corn and some other crop plants by as much as 100 per cent.

SOME PROBLEMS, HOWEVER

The story of antibiotics is not one of uninterrupted success. For one thing, they have not been effective against most viral diseases. Those antibiotics that are effective against viruses are highly toxic to normal body cells. Then, too, various antibiotics may produce undesirable side reactions. These effects may make themselves felt with the very first dose. Sometimes they develop after a person has received repeated doses. When broad-spectrum antibiotics are given by mouth, the growth of many of the bacteria normally found in the stomach is checked, and there is an overgrowth of various undesirable yeastlike or funguslike organisms.

A very serious problem with long-term or inappropriate use of antibiotics is the eventual *resistance* developed by bacteria to an antibiotic. A large population of bacteria often contains some members that are naturally resistant to the action of a particular antibiotic. While the less-resistant members of the population are destroyed, the hardy members grow and multiply, eventually forming a larger number of resistant bacteria. In other cases, some bacteria in a population may suddenly mutate, or change, becoming resistant to an antibiotic they were once sensitive to. Again, these resistant bacteria will then multiply.

In most cases, bacterial resistance develops against only one antibiotic and a second antibiotic can be used to wipe out the infection. A combination of the antibiotics is sometimes given to prevent the growth of resistant organisms at the outset.

selected readings

MAMMALS

GENERAL WORKS

Kurten, Bjorn. *The Age of Mammals.* New York: Columbia University Press, 1973; 250 pp., illus.—The history of life on earth during Cenozoic time, as described by a leading paleontologist in lively style.

Laycock, George. *People and Other Mammals.* Garden City, N.Y.: Doubleday, 1975; 143 pp., illus.—The natural history of many kinds of mammals, from shrews to whales.

Walker, Ernest P., et al. *Mammals of the World.* Baltimore: Johns Hopkins University Press, 3d ed., 1975; 2,142 pp., illus. —The standard reference book, in English, on living mammals.

Whitaker, John O. *The Audubon Society Field Guide to North American Mammals.* New York: Knopf, 1980; 745 pp., illus.—Compact guide with considerable information on the habits of individual species, attractively illustrated.

SEA MAMMALS

Baily, Jane H. *The Sea Otter's Struggle,* Chicago: Follett, 1974; illus.—Warmly written account of a typical sea otter's life and ecological role.

Cousteau, Jacques-Yves, and Philippe Diolé. *Diving Companions: Sea Lion, Sea Elephant, Walrus.* New York: Doubleday, 1974; 304 pp., illus.—Valuable mainly as a picture book.

——. *Dolphins.* Garden City, N.Y.: Doubleday, 1975; illus. —Sea-explorer Cousteau narrates his adventures with dolphins and describes the scientific research being done on them.

Dobbs, Horace. *Follow the Wild Dolphins.* New York: St. Martin's, 1982; 263 pp., illus.—The story of a personal friendship with a bottle-nose dolphin in the Irish Sea.

Ellis, Richard. *The Book of Whales.* New York: Knopf, 1980; 260 pp., illus.—Describes each whale in detail, with excellent illustrations by the author.

Stephen, David, ed., *Dolphins, Seals and Other Sea Mammals.* New York: Collins-Putnam, 1973; 88 pp., illus.—For all ages; a very good reference book with color photographs.

CATS AND DOGS

Carlson, Delbert G., D.V.M., and James M. Griffin, M.D. *Dog Owner's Home Veterinary Handbook.* San Francisco: Howell Books, 1980; 366 pp., illus.—Complete, up-to-date layperson's guide to veterinary medicine.

Cook, David and Valerie Pitt. *A Closer Look at Dogs.* New York: Franklin Watts, 1975; 30 pp., illus.—Dog behavior examined in terms of ancestral wolf behavior, with beautiful illustrations, for grades 5–12.

——. *A Closer Look at Great Cats.* New York: Franklin Watts, 1975; 30 pp., illus.—The behavior of great cats in the wild, with maps showing their distribution, and handsome pictures; grades 5–9.

Eaton, Randall L. *The Cheetah: The Biology, Ecology, and Behavior of an Endangered Species.* New York: Van Nostrand Reinhold, 1974; 178 pp., illus.—A summary of what is known about this fast-running large cat.

Thomas, Harold E. *Coyotes: Last Animals on Earth?* New York: Lathrop, Lee & Shepard, 1975; 124 pp., illus.—The behavior and intelligence of the coyote and its relation to the human environment; good for general lay audience.

Van Lawick, Hugo. *Solo: The Story of an African Wild Dog.* Boston: Houghton Mifflin, 1974; 159 pp., illus.—The real-life story of a pack of wild dogs in Africa, especially one named "Solo" by Van Lawick.

PRIMATES

Amon, Aline. *Reading, Writing, Chattering Chimps.* New York: Atheneum, 1975; 118 pp., illus.—A well-written account of our efforts to communicate with chimpanzees through visual signs and symbols; for grades 5–9.

Fossey, Dian. *Gorillas in the Mist.* Boston: Houghton Mifflin, 1983; 326 pp., illus.—Some events in a 13-year study of mountain gorillas in rain forests of central Africa.

Freeman, Dan. *The Great Apes.* New York: Bison Books/ Putnam, 1979; 192 pp., illus.—Clearly written account of the most current information on chimpanzees, gorillas, and orangutans.

MacKinnon, John. *In Search of the Red Ape.* New York: Holt, Rinehart & Winston, 1974; 222 pp., illus.—Naturalist describes his life in Borneo and Sumatra rain forests observing the orangutan; grades 7–12.

Napier, Prue. *Monkeys and Apes.* New York: Bantam, 1973; 159 pp., paperback, illus.—Covers both fossil and living primates; checklist of species is included.

OTHER MAMMALS

Bailey, Bernadine. *Wonders of the World of Bears.* New York: Dodd, Mead, 1975; 63 pp., illus.—Good reference for all kinds of bears; grades 5–9.

Conklin, Gladys. *The Llamas of South America.* New York: Holiday House, 1975; 64 pp., illus.—A simple, informative approach that works in the history of llamas and their possible extinction in the future.

Devereux, Frederick L., Jr. *Horses.* New York: Franklin Watts, 1975; 66 pp., illus.—Useful reference for younger readers already interested in horses.

Hanby, Jeannette. *Lion Share.* Boston: Houghton Mifflin, 1982; 221 pp., illus.—A true story of a pride of lions on the Serengeti plains of Africa.

Jenkins, Marie M. *Kangaroos, Opossums, and Other Marsupials.* New York: Holiday House, 1975; 160 pp., illus.—All the basic facts about pouched mammals.

Koch, Thomas J. *The Year of the Polar Bear.* Indianapolis: Bobbs-Merrill, 1975; 150 pp., illus.—The life of a polar bear in the Hudson Bay region; for grades 7 on up.

Laycock, George. *The Camels: Ships of the Desert.* Garden City, N.Y.: Doubleday, 1975; 58 pp., illus.—Good introductory account of camels and of their use by humans.

Lockley, R. M. *The Private Life of the Rabbit: An Account of the Life History and Social Behavior of the Wild Rabbit.* New York: Macmillan, 1974; 152 pp., illus.—The firsthand account of a naturalist.

MacClintock, Dorcas. *A Natural History of Giraffes.* New York: Scribners, 1973; 134 pp., illus.—Thorough review of what is known about the physiology and behavior of giraffes; striking silhouette illustrations.

Mellanby, Kenneth. *The Mole.* New York: Taplinger, 1973; 159 pp., illus.—The characteristics and behavior of the European mole, with a chapter on other animals with similar life-styles; for high school students.

Patient, Dorothy Hinshaw. *Weasels, Otters, Skunks and Their Family.* New York: Holiday House, 1973; 95 pp., illus.—The Mustelidae and their evolution, charmingly illustrated; for grades 5–9 or older.

Poling, James. *Beavers: Their Extraordinary Lives and Curious History.* New York: Franklin Watts, 1975; 85 pp., illus.—For junior high school readers.

Stadtfeld, Curtis K. *Whitetail Deer: A Year's Cycle.* New York: Dial, 1975; 163 pp., illus.—Through the story of Michigan's whitetail deer, the author provides good insights into interrelationships in nature; grade 7 on up.

Taketazu, Minoru. *Fox Family: Four Seasons of Animal Life.* Tokyo: Weatherhill (dist. by Charles E. Tuttle Co.), 1979; 139 pp., illus.—Elegantly written essay on the seasonal activities of foxes, accompanied by excellent photos.

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PHYSIOLOGY

Barash, David P. *Aging.* Seattle: University of Washington Press, 1983; 240 pp.—A readable exploration of the biological processes, history, and social aspects of aging.

Barnard, Christiaan, and John Illman, eds. *The Body Machine.* New York: Crown, 1981; 256 pp., illus.—A system-by-system look at the human body.

Bevan, James. *The Simon and Schuster Handbook of Anatomy and Physiology.* New York: Simon & Schuster, 1978; 96 pp., illus.—Useful simplified sourcebook.

Brooks, Stewart M. *Basic Science and The Human Body: Anatomy and Physiology.* St. Louis: C. V. Mosby, 1975; 481 pp., illus.—A clearly written introduction to human anatomy and physiology; suitable for high school readers.

Dement, William C. *Some Must Watch While Some Must Sleep.* San Francisco: W. H. Freeman, 1974; 148 pp., illus.—Fine introduction to sleep research; good for general reader and student alike.

Diagram Group. *The Brain: A User's Manual.* New York: Putnam, 1982; 191 pp., illus.—A visual approach to the study of the nervous system; for the general reader.

Elgin, Kathleen. *The Human Body: The Muscles.* New York: Franklin Watts, 1973; 72 pp., illus.—A good reference work for advanced elementary school students.

Knight, David C. *Your Body's Defenses.* New York: McGraw-Hill, 1975; 95 pp., illus.—The body's various ways of protecting itself, with a discussion of related diseases and conditions; grades 5–9.

McNamara, Louise Greep and Ada B. Litchfield. *Your Living Bones.* Boston: Little, Brown, 1973; 32 pp., illus.—For young readers, an accurate and well-illustrated account of the human skeleton.

Miller, Jonathan. *The Body in Question.* New York: Random House, 1979; 352 pp., illus.—New insights into human physiology over the centuries, well arranged.

———. *The Human Body.* New York: Viking, 1983; illus.—An atlas of human anatomy and a work of art, featuring pop-up three-dimensional models of the body; for junior high schoolers and adults.

Mylander, Maureen. *The Great American Stomach Book.* New Haven: Ticknor & Fields, 1982; 269 pp.—The workings of the digestive system and how to keep it in order.

Nilsson, Lennart, with Jan Lindberg. *Behold Man: A Photographic Journey of Discovery Inside the Body.* Boston: Little, Brown, 1974; 243 pp., illus.—Impressive photographs, many taken with light or electron microscopes, of anatomical features of the human body.

Stevens, Leonard A. *Neurons: Building Blocks of the Brain.* New York: Crowell, 1974; 87 pp., illus.—The history of the study of the neuron and how it functions in the body; grades 7–12.

Stonehouse, Bernard, et al. *The Way Your Body Works.* New York: Crown, 1974; 96 pp., illus.—Well-illustrated text on human structures and their functions, in atlas format, with chapters on growth, disease, evolution, and so forth; for student or layman.

HEALTH AND DISEASE

Ammer, Christine. *The A to Z of Women's Health.* New York: Facts on File, 1983; 481 pp., illus.—A comprehensive guide to women's bodies from birth to old age.

Ashley, Richard, and Heidi Duggal. *Dictionary of Nutrition.* New York: St. Martin's, 1975; 236 pp., illus.—Practical reference guide to nutritional information, including nutrition-related diseases; senior high.

Braverman, Jordan. *The Consumer's Book of Health.* Philadelphia: W. B. Saunders, 1982; 305 pp.—How to find and evaluate health-care services.

Cain, Arthur H. *Young People and Health.* New York: John Day, 1973; 171 pp., illus.—General, well-balanced review of diet, weight, exercise, and other health matters.

Carroll, David. *The Complete Book of Natural Medicines.* New York: Summit Books, 1980; 416 pp., illus.—A compendium of natural home remedies, with easy-to-follow directions for treating common ailments.

Denney, Myron K., M.D. *Second Opinion.* New York: Grosset & Dunlap, 1979; 204 pp.—Helps patients provide their own second opinion by describing why half of all operations may be unnecessary.

Finnerty, Frank A., Jr., and Shirley Motter Linde. *High Blood Pressure: What Causes It, How to Tell If You Have It, How to Control It for a Longer Life.* New York: McKay-Pavillion, 1975; 299 pp., illus.—Two experts in the field of high blood pressure describe its physiology, diagnosis, and treatment; senior high on up.

Glucksberg, Harold, and Jack W. Singer. *Cancer Care.* New York: Scribners, 1982; 435 pp.—Nontechnical explanations of the types of cancers, treatments, and the role of heredity and environment in the disease.

Gregg, Walter H. *Physical Fitness Through Sports and Nutrition.* New York: Scribners, 1975; 112 pp., illus.—Readers, grades 5 through 12, are encouraged to find a good conditioning program and appropriate sport for themselves; background discussion of physiology.

Hyde, Margaret O., and Elizabeth Held Forsyth. *What Have You Been Eating? Do You Really Know?* New York: McGraw-Hill, 1975; 146 pp., illus.—A sensible review of nutrition, foods and additives, diets, food faddism, and related topics; for the general reader.

Klein, Stanley. *The Final Mystery.* New York: Doubleday, 1974; 86 pp., illus.—Human concepts of death through the ages, for grades 5–9.

Leisy, Jim. *Calories In/Calories Out.* Brattleboro, Vt.: Stephen Greene Press, 1981; 128 pp., illus.—Refreshing facts-and-figures, rather than pop-psychological, approach to weight control and fitness.

Long, James W. *The Essential Guide to Prescription Drugs.* New York: Harper & Row, 1982; 935 pp.—A source of basic information about commonly used drugs.

Majno, Guido. *The Healing Hand: Man and Wound in the Ancient World.* Cambridge, Mass.: Harvard University Press, 1975; 571 pp., illus.—Shows the common sense behind many ancient medical practices; for grade 7 on up.

National Research Council. *Diet, Nutrition, and Cancer.* Washington, D.C.: National Academy Press, 1982; 496 pp.—A summary of the most significant information on diet and cancer, with recommended dietary guidelines.

Peavy, Linda, and Ursula Smith. *Food, Nutrition, and You.* New York: Scribners, 1982; 197 pp., illus.—The body's nutritional needs; directed at teenagers.

Pilgrim, Ira. *The Topic of Cancer.* New York: Crowell, 1974; 255 pp., illus.—A compassionate review of cancer research and its relationship to actual human experience.

Regestein, Quentin R., and James R. Rechs. *Sound Sleep: Key to a Healthier Life.* New York: Simon & Schuster, 1980; 288 pp.—Causes and cures of sleep disorders, in a well-conceived self-help book.

Seymour, Rogers James. *The Heart Attack Survival Manual: A Guide to Using CPR (Cardiopulmonary Resuscitation) in a Crisis.* New York: Spectrum/Prentice Hall, 1981; 117 pp., illus.—This fine work, one of few on the subject, describes signs of a heart attack and how to administer CPR in a variety of circumstances.

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Arehart-Treichel, Joan. *Biotypes: The Critical Link Between Personality and Health.* New York: Times Books (dist. by Harper & Row), 1980; 288 pp.—Examines the mind-body link in personal health and suggests that a greater understanding of the relationship between personality and health may lead to disease prevention through behavior modification.

Cohen, Daniel. *Intelligence: What Is It?* New York: M. Evans, 1974; 159 pp., illus.—For junior high school on up; a well-balanced discussion of what is meant by "intelligence" and the pros and cons of intelligence tests.

Howells, John G., ed. *World History of Psychiatry.* New York: Brunner/Mazel, 1975; 770 pp., illus.—A comprehensive reference work that really does include the whole world, with good bibliographies; for senior high on up.

Laiken, Deidre S., and Alan J. Schneider, *Listen to Me, I'm Angry.* New York: Lothrop, Lee & Shepard, 1980; 106 pp.—Lucid, highly practical explanation of a complex emotion; written for young people.

Lieberman, Morton A., and Sheldon S. Tobin. *The Experience of Old Age.* New York: Basic Books, 1983; 439 pp., illus.—An examination of the responses of the elderly to relocation and other major stresses.

London, Perry. *Beginning Psychology.* Homewood, Ill.: Dorsey Press, 1975; 655 pp., illus.—For the advanced reader; a clear and well-written text that also includes discussions of vocational and avocational aspects of life.

McGough, Elizabeth. *Your Silent Language.* New York: Morrow, 1974; 128 pp., illus.—For the lay reader, a good introduction to "kinesics," the nonverbal communication known as "body language."

Suinn, Richard M. *Fundamentals of Behavior Pathology.* New York: John Wiley, 2d ed., 1975; 595 pp., illus.—For the older reader who is not a psychology major; an interesting introduction to the subject of abnormal behavior.

DRUGS AND SMOKING

Edwards, Gabrielle I. *The Student Biologist Explores Drug Abuse.* New York: Richards Rosen Press, 1975; 112 pp., illus.—A brief, factual review of commonly abused drugs; slang terms are included to help identify specific drugs.

Fleming, Alice. *Alcohol: The Delightful Poison: A History.* New York: Delacorte, 1975; 138 pp., illus.—Insights into the uses and abuses of alcohol by societies throughout history, along with the social impact of alcoholism; for grades 7–12.

Fried, Peter A., and Harry Oxron, M.D. *Smoking for Two: Cigarettes and Pregnancy.* New York: Free Press, 1980; 151 pp.—If you are, don't. Timely and up-to-date, both scientifically and socially.

Madison, Arnold. *Smoking and You.* New York: Julian Messner, 1975; 64 pp., illus.—A simple account of the facts known about smoking and health; for younger readers.

Tracy, Don. *What You Should Know About Alcoholism.* New York: Dodd, Mead, 1975; 157 pp., illus.—Simple and direct advice on how to deal with and give help to an alcoholic; for the general reader.

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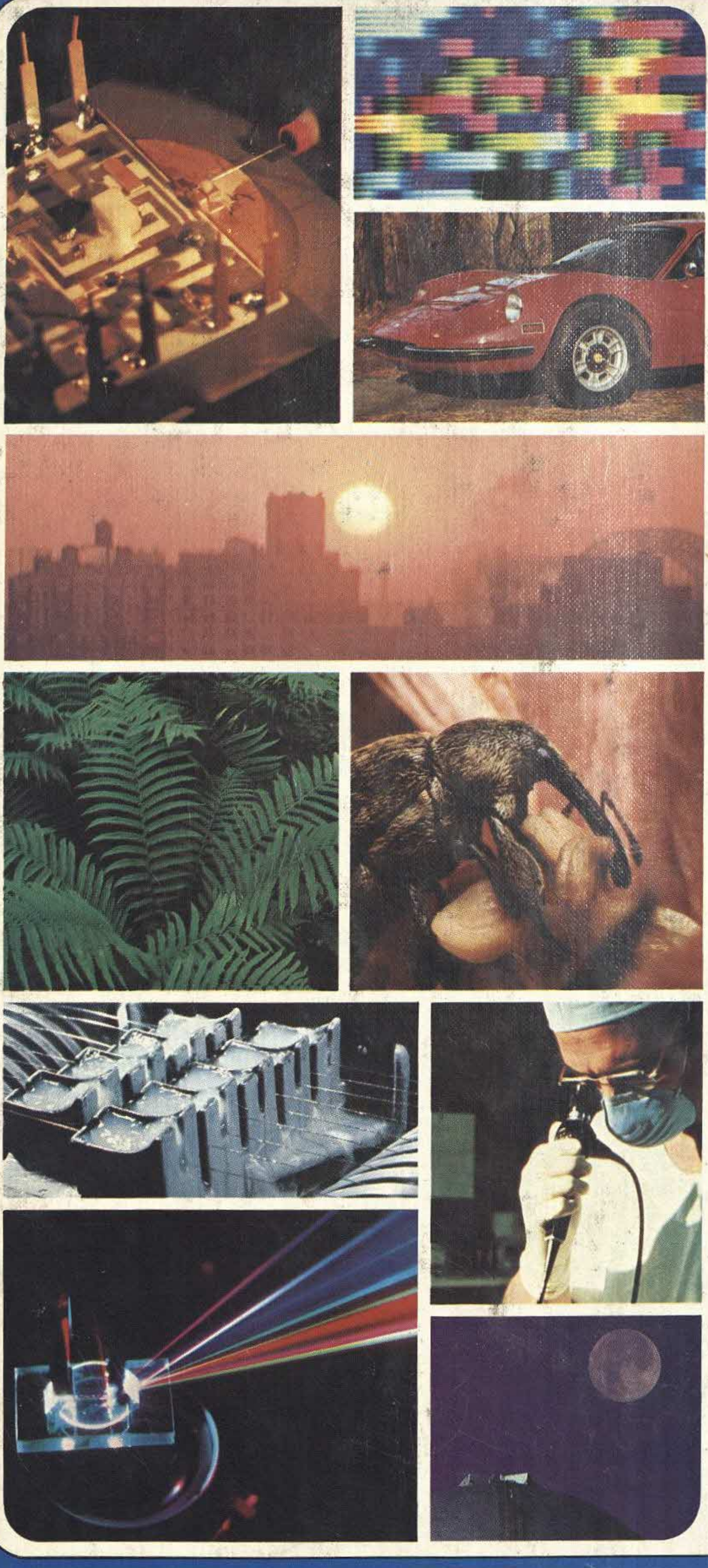

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